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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Principal: J. C. M. Garnett, M.A. (late Fellow Trin. Coll. Cam.).

Vice-Principal: B. M. Wrong, M. A. (Fellow Magdalen Coll., Oxford).

The Session 1918-1919 will open on 3rd October. Matriculation and Entrance Examinations will be held in July and September. Matriculated students may enrol for 1918-19 from 1st August, 1918, and if under 18 years of age are eligible for membership of the Officers' Training Corps.

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The University of Sheffield.

SESSION 1918-19.

Vice-Chancellor—W. Ripper, C.H., D.Eng., D.Sc., M.Inst.C.E., J.P.

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Mechanical Engineering—W. Ripper, C.H., D.Eng., D.Sc., M.Inst.C.E., J.P.
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Mining—F. E. Armstrong, M.Sc., A.M.Inst.C.E.
Applied Chemistry—L. T. O'Shea, M.Sc.
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Physics—S. R. Milner, D.Sc.
Chemistry—W. P. Wynne, D.Sc., F.R.S.
Geology—W. G. Fearnsides, M.A.

Electrical Engineering—B. H. Chapper, B.Eng., M.I.E.E. (Lecturer).
Civil Engineering—J. Husband, B.Eng., A.M.Inst. C.E. (Lecturer).
Glass Technology—W. E. S. Turner, D.Sc. (Lecturer).

The subjects in which courses of study are provided include Engineering, Metallurgy, Coal Mining, Applied Chemistry, Mathematics, Physics, Chemistry, Geology, Glass Technology and Refractories.

The DEPARTMENT OF ENGINEERING includes courses in Civil, Mechanical, Electrical and Chemical Engineering, and students specialise in one or other of these branches in the third year of their course. The Course in Engineering extends over three years and prepares for the degree of Bachelor of Engineering (B.Eng.) or for the Associateship of the University in Engineering. Special three years' courses are arranged for Works' pupils, who come to the University from the works in Sheffield, or from other centres, taking six months' study at the University and six months' practice at the works each year.

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The LECTURE COURSES commence 2nd October, 1918.

The TECHNICAL LABORATORY COURSES commence 23rd September, 1918. L 940

W. M. GIBBONS, Registrar.

University of Manchester.

Department of ELECTRICAL ENGINEERING.
Departments of CIVIL, MECHANICAL and ELECTRICAL ENGINEERING.

Full particulars of these courses will be forwarded on application to the REGISTRAR. M 478

The Session commences on the 3rd October.

The Royal Technical College, GLASGOW.

SESSION 1918-19
BEGINS ON SEPTEMBER 24TH.

The DIPLOMA of the COLLEGE is granted in the following departments—Civil Engineering, Mechanical Engineering, Electrical Engineering, Mining, Naval Architecture, Chemistry, Metallurgy, Building, Textile Manufacture, Dyeing, and Sugar Manufacture.

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ENGINEERING AND TECHNICAL OPTICS.

Northampton Polytechnic Institute, St. John Street, London, E.C. 1.

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Full Day Courses in the Theory and Practice of Civil, Mechanical and Electrical Engineering will commence on Monday, 30th September, 1918. The Courses in Civil and Mechanical Engineering include specialization in Automobile and Aeronautical Engineering, and those in Electrical Engineering include specialization in Radio-Telegraphy. *Entrance Examination* on Tuesday and Wednesday, 24th and 25th September, 1918. These courses include periods spent in commercial workshops and extend over four years. They also prepare for the Degree of B.Sc. in Engineering at the University of London. Fees, £16 or £11 per annum. *Three Entrance Scholarships* of the value of £52 each will be offered for competition at the entrance examination in September, 1918.

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Full and Part Time Courses in this important department of Applied Science will be given in specially equipped laboratories and lecture rooms. An *Aitchison Scholarship* (value £35) will be offered in this department at the entrance examination.

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R. MULLINEUX WALMSLEY, D.Sc., Principal. M 378

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Day and Evening Classes in Engineering (Civil, Electrical, Mechanical and Marine)

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Paddington Technical Institute, Saltram Crescent, W. 9 (Mechanical and Electrical).

School of Engineering and Navigation, High Street Poplar, E. 14 (All except Civil Engineering).

Westminster Technical Institute, Vincent Square, S.W. 1 (Civil Engineering in the evening).

In most cases persons under 21 qualified for admission to the schools or institutes and bona fide engaged in the Trade are admitted free.

Full prospectuses may be obtained on application to the Secretaries of the respective institutions.

JAMES BIRD, M 606
Clerk of the London County Council.

UNIVERSITY OF LONDON.

King's College.—Faculty of Engineering.

Complete COURSES of STUDY, extending over either three or four years, are arranged in CIVIL, MECHANICAL and ELECTRICAL ENGINEERING for the Engineering Degrees of the University of London and for the Diploma and Certificate of the College.

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Professor A. H. Jameson, M.Sc., M.Inst.C.E.	Civil Engineering.
Professor E. Wilson, M.Inst.C.E., M.I.E.E., Dean	Electrical Engineering.
Professor S. A. F. White, M.A. ...	
Professor J. W. Nicholson, M.A., D.Sc.	Mathematics.
Professor Sir H. Jackson, K.B.B., F.R.S....	Chemistry.
Professor A. W. Crossley, D.Sc., F.R.S....	
Professor O. W. Richardson, D.Sc., F.R.S....	Physics.
Professor A. K. Huntington, M.I.M.M.	Metallurgy.
Mr. W. T. Gordon, D.Sc., F.R.S.E.	Geology.

Considerable additions have been made to the Engineering Department. These include a large drawing office and lecture rooms for the Mechanical and Civil Engineering Departments and lecture theatre and rooms for research, including Wireless Telegraphy for the Electrical Engineering Department. There are five laboratories well equipped with engineering plant and apparatus for the purpose of teaching and research.

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For full information apply to the DEAN, or the SECRETARY, King's College, Strand, W.C. 2. M 619

UNIVERSITY OF LONDON,

University College.

SESSION 1918-19.

FACULTY OF ENGINEERING.

The SESSION BEGINS on MONDAY, SEPTEMBER 30th.

DEGREE and DIPLOMA COURSES.

Students desirous of entering the Faculty of Engineering, with a view to taking a full Degree or Diploma Course, must have passed the Matriculation Examination, or some other examination accepted in its stead.

SPECIAL COURSES.

Students who have already undergone a partial training elsewhere, and who have attained a sufficient standard, may enter for a course occupying less than three years, and may obtain a General Certificate of Engineering after not less than two consecutive Sessions' attendance

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Graduates in Science or Engineering, or Stupents who have done the work equivalent to a Degree, may be admitted to Special Courses of Study, or to prosecute original research.

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A Goldsmid Entrance Scholarship tenable in the Faculty of Engineering, value £90, will be competed for in September. Application for Entry Forms must be made not later than September 10th.

ADMISSION.

Intending Students should communicate with the Provost as soon as possible (and in any case not later than September 14th), and should send a full statement of their previous training.

Full particulars may be obtained on application to the undersigned—

WALTER W. BENTON, M.A., D.Lit., Secretary.
University College, London, Gower Street, W.C. M 620

The Polytechnic, Regent Street, W. 1. SCHOOL OF ENGINEERING.

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Head of Department: Henry J. Spooner, M.I.Mech.E., A.M.Inst.C.E., M.Inst.A.E., F.G.S., etc.

The DAY DEPARTMENT RE-OPENS on 17th SEPTEMBER, 1918.
(ENTRANCE EXAMINATION 16th SEPTEMBER, at Ten o'clock.)

Three Year DIPLOMA COURSES in
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Practice in the Laboratories, Drawing Office, Workshops and Field. Fees—£16 16s. per annum.

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Full Prospectus, &c., free on application to—
THE DIRECTOR OF EDUCATION. M 607

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Forms of Tender, &c., may be obtained on application to THE CONTROLLER OF SUPPLIES, H.M. Office of Works, &c., King Charles Street, Westminster, London, S.W. 1. M 647

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The highest, or any, Tender not necessarily accepted. M 649

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Application is Invited from

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J. C. MAXWELL GARNETT,
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MANCHESTER MUNICIPAL COLLEGE OF TECHNOLOGY.

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Amended Advertisement.

Principal of Technical College

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A. C. BOYDE,
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Darlington,
August, 1918. M 550

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E. SALTER DAVIES,
Director of Education.
August, 1918. M 611

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Applicants must be experienced in the supervision of pumping machinery and control of men, should have a knowledge of water purification by means of Chlorine and Alum no-ferric process, and the operation of pressure filters.

Salary £4 to £4 10s. per week, according to experience and ability.

Applications from ineligible or low category men, stating age, qualifications and experience, and accompanied by copies of recent testimonials, should be forwarded as soon as possible marked "Water Manager" on envelope, and addressed to BOX 457, Willings, 125, Strand, London, W.C. 2. M 626

COUNTY BOROUGH OF SALFORD.

ELECTRICITY DEPARTMENT.

Applications are Invited for

the position of BOILER HOUSE SUPERINTENDENT, to take charge of Lancashire and Water Tube Boilers, including operation and maintenance. Applicants must have practical knowledge of boiler-house operations and be able to carry out efficiency tests and the testing of fuel. Applications, stating age, qualifications and salary, to be forwarded to the Borough Electrical Engineer, Frederick Road, Salford, not later than Monday, 16th September, 1918. M 603

L. C. EVANS,
Town Clerk.

Chief Clerk to Works Manager

WANTED for high-class Engineering works on Clydeside. Must be able to take shorthand and conduct correspondence. Good opening for qualified man. No one already on Government work need apply.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5979. M 601

Managing Director Required

for Stamped Brass and Metal Manufacturing Company in Birmingham. Must be capable; take entire charge of works. Can invest up to £3000. Good opportunity for right man.—Address, M 304, Offices of Engineering.

The Directors of an Important

Birmingham Manufacturing Company allied with engineering and shipbuilding are OPEN to APPOINT a GENTLEMAN with high-class business and commercial experience to a post as right-hand man to the Managing Director.—Applications, which will be treated in confidence, are invited from discharged service men and others, and may be addressed to M 683, Offices of Engineering.

A NEW THEORY OF THE STEAM TURBINE.

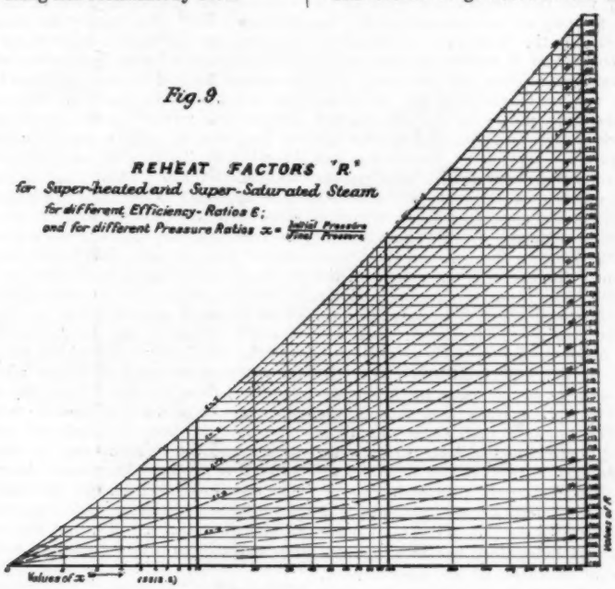
By HAROLD MEDWAY MARTIN, Wh.Sc., A.C.G.I.

(*Concluded from page* 191.)

That vacuum corrections are quite irrational on the ordinary theory has long been recognised. On this theory with high-pressure turbines a reduction of the exhaust pressure from 1 lb. absolute to ½ lb. absolute should reduce the steam consumption by some 11 per cent., whereas experience shows that the actual improvement in the steam rate is only some 6 per cent., or, according to some builders, 5 per cent.

As a matter of fact the real discrepancy is somewhat less than these figures would imply as no allowance has been made for the fact that the increase of vacuum involves an increase in the total effective thermodynamic head. Hence the average ratio of blade speed to steam speed is less with the higher vacuum, and there is, in consequence, a reduction in the hydraulic efficiency of the turbine, the greater head corresponding to the higher vacuum being less economically used.

Fig. 9.


REHEAT FACTORS 'R'
for Super-heated and Super-Saturated Steam
for different Efficiency-Ratios ε;
and for different Pressure Ratios x = Initial Pressure / Final Pressure
Values of x
Values of R

It should be noticed, moreover, that whilst an increase in the thermodynamic head due to superheat affects the whole turbine from end to end, this is not the case when the increase in the head is due to a higher vacuum. The effect of changes in the vacuum is, in fact, strictly local. This is perhaps most obvious in the case of a certain well-known impulse turbine which is designed so that with normal vacuum the velocity of efflux from the last row of guide blades is slightly above the critical value. This critical value of the velocity is the speed of sound, and as this is the speed with which any disturbance is propagated through a medium, the "news" of an improvement in the vacuum can never get back past the last row of nozzles. In fact, the last wheel is the only working element of the turbine that can ever get to "know" that the vacuum has been increased. All the other stages will continue to work under the same conditions and with the same efficiency as before. The whole effect of the increase of vacuum is thus concentrated on the last stage where both the nozzle and the wheel efficiencies will be reduced. The total resultant loss of efficiency of the turbine as a whole will be greater than if the increase in the thermodynamic head had been equally divided between all its stages.

This will be readily seen by considering the case of a turbine consisting of two equal stages which, in order to avoid complications due to "reheat," will be assumed to be operated by water. Suppose that in normal conditions this turbine works with its maximum efficiency, η_1 say, and that the efficiency curve for each stage is a parabola, an assumption which experience shows is approximately true. Let δ_1 be the ratio of blade speed to water speed corresponding to η_1. Then at any other ratio of blade speed to water speed the efficiency η will be:

$$\eta = \eta_1\left(\frac{2\,\delta}{\delta_1} - \frac{\delta^2}{\delta_1^2}\right).$$

Suppose now that the total head is doubled whilst the blade speed remains unchanged. Then if this increase of head be equally divided over the two stages, the ratio of blade speed to water speed will be diminished in the ratio of 1 to $\sqrt{2}$, so that the efficiency under the changed conditions will be:

$$\eta = \eta_1\left(\frac{2}{\sqrt{2}} - \frac{1}{2}\right) = 0.914\,\eta_1$$

If, on the other hand, the whole of the increase of head is concentrated on the second stage, the efficiency of the first stage will remain η_1, but as the second stage will now be operating under three times its proper head, its efficiency will be:

$$\eta = \eta_1\left(\frac{2}{\sqrt{3}} - \frac{1}{3}\right) = 0.821.$$

This second stage accounts for three times the head expended in the first stage, so that the average efficiency of the turbine as a whole is

$$\tfrac{1}{4}\,\eta_1 + \tfrac{3}{4}\,0.821\,\eta_1 = 0.866\,\eta_1$$

as compared with $0{\cdot}914\,\eta_1$ when the increase of head was equally divided between the two stages.

It is thus not permissible to use the same efficiency curve for computing changes in the steam rate consequent on an increase of vacuum as is appropriate for estimating changes due to variations in the superheat. Nevertheless, a comparison between observation and calculation made with the aid of Fig. 7, page 189 *ante*, is not without interest.

Following the method already described in detail in computing superheat corrections, calculation on these lines gives a 7·5 reduction in the steam rate when the normal exhaust pressure of 1 lb. absolute is reduced to ½ lb. absolute, the normal hydraulic efficiency of the turbine being taken as 0·7. Observation gives, as already stated, 6 per cent. as the actual figure in the case of ordinary reaction turbines, and 5 per cent. in the case of the type of turbine above referred to, in which the critical velocity is attained at the last stage in normal working. The difference between the calculation and the results of observation is thus not larger than might be anticipated from the fact that the increase of head due to the higher vacuum is concentrated on a very small fraction of the complete turbine, and the consequent reduction of efficiency is therefore greater than represented by the efficiency curve plotted in Fig. 7. The outstanding discrepancy is of the right sign and order, and the actual result seems to confirm the general accuracy of the "equivalent reheat factors" shown in the diagram, Plate I *ante*.

More than this should not be expected from the existing data, which have necessarily been obtained under other than laboratory conditions. More precise figures will no doubt be available later on, and may necessitate some slight modification in the values of R_w. Possibly the lines in the diagram for R_w, Plate I, should be bands rather than lines, since the steam during its expansion beyond the Wilson line is in a dynamic condition, and it would be natural to expect accordingly that the equivalent reheat factor should not be wholly independent of the time taken for the steam to pass through the turbine.

With the diagrams of reheat factors given on Plate I *ante* it is easy, knowing the hydraulic efficiency of a turbine, to calculate its steam rate. The converse problem of determining from an observed steam rate the average hydraulic efficiency of a turbine is less simple, and a process of trial and error was adopted in determining the points plotted in Figs. 7 and 8, on pages 189 and 190 *ante*. This is somewhat laborious, and the following simple plan which, whilst not determining the actual value of the hydraulic efficiency, does fix for it both a higher and a lower limit, may be of service.

From a point on the steam chart corresponding to the initial temperature and pressure of the steam draw a horizontal to cut the final pressure. Let the length of this line measured on the scale for heat units be u^1. Note where this horizontal cuts the Wilson line, and let the distance (measured in heat units) between this point and the point of intersection of the horizontal line with the terminal pressure be u^1_w. Let x be the ratio of the "Wilson" pressure to the final pressure, and from the diagram of equivalent reheat factors take out R_w for unit efficiency. Then the equivalent "effective efficiency ratio" is less than

$$\epsilon_1 = \frac{1{,}895{\cdot}5}{u^1\,W}$$

and more than

$$\epsilon_2 = \frac{1{,}895{\cdot}5}{W\,[u^1 + u^1_w(R_{w_1} - 1)]}$$

where heat quantities are taken in pound Centigrade units and W denotes the actual observed consumption in pounds per kilowatt-hour.

If from the diagram, Fig. 9, we take out R_1 corresponding to ϵ_1 and R_2 corresponding to ϵ_2, then the hydraulic efficiency of the turbine is less than $R_1\,\epsilon_1$, and greater than $R_2\,\epsilon_2$.

In plotting the efficiency curves, Figs. 4, 7 and 8, pages 107, 189 and 190 *ante*, a certain coefficient K has been employed. From inquiries received it would seem that the method of determining this coefficient is less generally understood than the writer had believed.

In the case of a simple impulse turbine having all its wheels of the same mean diameter d, we have simply:

$$K = n\left(\frac{d}{10}\right)^3\left(\frac{R.P.M.}{100}\right)^2$$

where n denotes the number of pressure stages and d is expressed in inches. In this case the number of pressure stages is equal to the number of wheels.

In certain large impulse turbines, however, the exhaust end is constructed on the double-flow principle. In that case n is less than the number of wheels, since in the double-flow section there are two wheels to each pressure stage.

Again, the turbine may have a varying mean diameter. Thus, suppose there are n_1 pressure stages of mean diameter d_1, n_2 of mean diameter d_2 and n_3 of mean diameter d_3. Then the value of K is given by:

$$K = \left[n_1\left(\frac{d_1}{10}\right)^3 + n_2\left(\frac{d_2}{10}\right)^3 + n_3\left(\frac{d_3}{10}\right)^3\right]\left(\frac{R.P.M.}{100}\right)^2$$

In other cases the high-pressure end of the turbine is velocity compounded. The velocity-compounded wheel has generally two moving rows of blades, each of the same mean diameter d_0, say. According to Mr. H. L. Guy,* the efficiency would be unaltered if this velocity-compounded stage were replaced by three simple impulse stages. Hence, if the actual

* Manchester Association of Engineers, "Steam Turbines for Land Purposes," by Mr. H. L. Guy, A.M.I. Mech.E., A.M.I.C.E. Reprinted in ENGINEERING, March 16, 1917, page 244.

turbine consisted of a velocity-compounded wheel of mean diameter d_0 followed by n_1 simple impulse stages of mean diameter d_1, the equivalent K for this machine would be:

$$K = \left[3\left(\frac{d_0}{10}\right)^2 + n_1\left(\frac{d_1}{10}\right)^2\right] \text{R.P.M.}$$

Though this rule may be used to bring results obtained with velocity-compounded turbines into line with results from turbines of the straight impulse type, it is a rule which cannot be relied on to "work both ways." If a velocity-compounded turbine were derived from a given impulse turbine by replacing three pressure stages of the latter by a velocity-compounded wheel it would, in fact, be unsafe to assume that the efficiency would be unaltered. The reason for this lies in the circumstance that it is impossible to attain as high a limit of efficiency with a velocity-compounded turbine as is possible with the straight impulse type. Hence, if the latter is designed for maximum efficiency, the substitution of a velocity-compounded wheel to replace some of its pressure stages will reduce the efficiency. Nevertheless, if the contract requirements demand something less than the maximum possible efficiency the required result may often be more cheaply and conveniently attained by the adoption of a velocity-compounded high-pressure end, and in such cases the rule above given is applicable.

In calculating K for reaction turbines it is usual to take n as the number of rows of moving blades. Theoretically, in order to compare with the rule for impulse turbines n should be the total number of pressure stages, but the practice has been, as stated, to take n as equal to the number of moving rows of blades. In other respects K is calculated exactly in the same way as for a straight impulse turbine in which the wheel diameters differ in different sections; and as in that case, where double flow is adopted, only one set of blades is counted when computing K.

Returning from this digression, the writer will conclude by recapitulating the principal points of the new theory advanced in this series of articles. Starting from the now accepted view, that wet steam is not discharged from a nozzle in a condition of thermal equilibrium, reasons have been given for believing that in actual turbine practice, the expansion of wet steam never does occur in a condition of thermal equilibrium. Evidence of this is afforded by the condition of the steam in the exhaust branch of a turbine, where temperature measurements do not correspond with the pressure of the steam as simultaneously observed. True, the apparent defect of temperature is small, but it has been pointed out that the kinetic theory of gases requires that the readings of a thermometer immersed in under-cooled steam should correspond to the pressure rather than to the temperature of this steam. That the true defect of temperature may amount to many degrees, may, it was pointed out, be inferred from Wilson's experiments on the expansion of supersaturated vapour, where, when the expansion was continued beyond the point at which moisture first separated out, the additional condensation came on new nuclei, and these nuclei can be effective only when the defect of temperature amounts to some tens of degrees.

It was shown that on this hypothesis a rational explanation of the anomalies in superheat and vacuum corrections became possible, thus bringing theory into accord with actual experience.*

THE MOUNT WILSON OBSERVATORY, CALIFORNIA.

THE great feat of constructing a giant reflector of 100 in. aperture, with all such an enterprise involves, has surrounded the Mount Wilson Observatory with a world-wide interest. More than ten years have passed since the scheme was set on foot, and that fact alone should convey some idea of the magnitude of the task undertaken, the labour expended and the difficulties that have been surmounted. From time to time we have reported progress, and though this progress may have appeared slow it has been continuous, and now the recently-issued report of the director leads us to believe that the giant reflector has reached such an advanced stage that its final tests are being conducted or may be already completed. When last referring to the erection, it was mentioned that the more important portions, such as the mercury tanks and floats, the sections of the polar axis and the main bearings had been fitted together, tested and transported to Pasadena. These are all now assembled in place, and the rotation of the instrument on its bearings has been critically examined. The right ascension and declination slow and fast motions have been completed and attached, the large driving worm-wheel has been cut and partially ground, the mirror cell has been fitted, and the support system installed. The Cassegrain cage has been riveted together and ground true, and the mirror elevator has been assembled and tested.

Concurrently with this preparatory work on the mountain, the figuring of two convex mirrors has been completed in the workshop at Pasadena. It was found convenient to utilise the large mirror in hyperbolising these mirrors, but this work being finished, there was no reason to delay the transportation of the huge mirror to the observatory. This was a work of some anxiety and difficulty that has been happily accomplished. The mirror was crated in a strong box lined with building paper and supported on its edge by a heavy framework bolted to the lid of the motor truck, the vibration in carriage being reduced by the insertion of numerous springs between the box and the framework. The top of the mirror when placed on the truck was about 14 ft. from the ground and the weight of the whole with the support was 7·5 tons. Nevertheless the trip up the mountain track was made without incident, the specially-geared truck performing its work without difficulty. On the successful achievement of this stage in the history of the great telescope, a stage that records the assemblage of all the massive parts at the summit of Mount Wilson and suggests unremitting perseverance in the past, combined with skill and resource, we offer our congratulations to all concerned.

The work on the 100-in. telescope has not exhausted the activity of the optical and mechanical staff. The Physical Laboratory has been doubled in area, a sufficient indication of increased activity, and a number of new investigations are contemplated, or those in progress, continued under improved conditions. Very much work has been done with the electric furnace and more powerful apparatus has been erected. The installation of the interferometer spectograph has been improved, and arrangements have been provided that will admit the erection of a plane grating spectograph of longer focus than now in use. A new Etalon, embodying the improvements indicated by experience, has been constructed and has already proved a welcome addition. The frame, which is entirely of steel, designed to give extreme stiffness and stability, will accommodate plates of different thickness, with separators of fused quartz up to 20 mm. in length. Six of these separators have been completed having lengths of 2·5 mm., 5 mm., 7·5 mm., 10 mm., 15 mm. and 20 mm. respectively. Under actual working conditions the apparatus is remarkably insensitive to thermal and mechanical disturbances—the whole order of interference is constant for a period of many weeks, and the corrections necessary from time to time to insure parallelism of the plates are exceedingly minute. Changes in thickness occurring during a day's observations amount, at a maximum, to only one part in a million.

In the optical shop, two large oval plane mirrors to be used with the 100-ft. reflector have been shaped and fine ground, two mirrors, 9 in. diameter, have been completed for use in the caudé form of the telescope, when only the centre of the field is employed; two 12-in. plane mirrors for use with the Snow telescope have been completed, together with much smaller work. Incidentally in connection with mirror grinding the question arose how far the Foucault knife-edge test could be relied on for large surfaces, and the result of a severe examination has been to show that it is possible to detect a general curvature amounting to only one seventy-fifth of a wave length, without regard to the absolute size of the surface. This result is very satisfactory, for further improvements depend largely on increase in accuracy of optical surfaces.

To attempt to describe what has been accomplished, within even one short year, by the use of this collection of instruments, that are kept at work, night and day, either collecting information direct from the heavens, or in investigating the truth of hypotheses that are suggested by such observations, hardly comes within the scope of these columns. To some the catalogue might prove wearisome or unmeaning. To have traced the ninth satellite of Jupiter, for example, and to have determined its position may not appear a matter of prime importance in these exciting times, to those who, recalling the time when Jupiter had only four satellites may remind us "that the world went very well then." Similarly, to those who have not mastered all that is involved in the determination of the distance of a star by the examination of its spectrum, it may seem a slight thing to be told that the parallaxes of some hundreds of stars have been measured with an accuracy equal to that secured by the trigonometrical method. The construction of an accurate mental picture of the stellar universe is, however, brought appreciably nearer by such knowledge. To be able to measure the rotational and radial velocity of the Andromeda nebula with some approach to certainty is a great achievement, however it may be regarded by those whose interests do not pass beyond our own atmosphere. To suggest that the solar field might deviate from that of a spherical magnet is not perhaps a great effort of the imagination, but to determine the inclination of the magnetic axis to that of rotation is a triumph of acute reasoning and observational skill. These remarks recall only a few of the subjects on which the astronomical staff at Mount Wilson has, under the direction of Professor Hale, laboured with diligence and success, and it must be admitted that to appreciate the present standpoint of astronomical science and the effort needed to advance beyond, requires a special education. Astronomy is not however so remote from the practical affairs of life as a superficial estimate might conceive it. Poincaré intimated, and with truth, that the world's civilisation would be in a very backward state if the stars had always been hidden by clouds. And in inviting us to think of the work of astronomical science he made no mention of such obvious conveniences as the determination of time or the assistance given to navigation. He considered such trifles as insignificant in comparison with the more impressive contributions of astronomy. It is from this bolder outlook that we have to contemplate the work at Mount Wilson. "Thanks to observations in all quarters of the earth," says the director, the picture of the Universe still continues to unfold and to influence progress in every field of thought. We are happily in a period of unprecedented progress, when the empirical conceptions of an earlier time are rapidly giving place to well-grounded views. The privilege of aiding in this advance, at a time when the pioneer stage has not yet been passed, will be appreciated by those who reflect on the true meaning and influence of astronomical discovery.

BRITISH SCIENTIFIC PRODUCTS EXHIBITION.

(*Concluded from page* 236).

Coil-Winding Machines—In concluding our notice of the Exhibition we begin with a description of the interesting Leesona Universal Electric Coil Winding Machines, to which we briefly referred last week. The Igranic Electric Company, Ltd., of 147, Queen Victoria Street, E.C., are the sole agents in the United Kingdom for these machines, which are claimed to produce all kinds of electric coils with a minimum production of scrap and minimum liability to breakdown. There are three types of Leesona machines: No. 84, which, by

* ERRATA.—On page 54 the formula below Table III. column 3, should read:

$$s = \frac{A}{T^k} - \phi_1 + \frac{k}{T^k}\int T^{k-1}\phi_1 \, . \, dt$$

On page 162, column 1, in the second paragraph, line 4 from the commencement, for 7½ times read 7 times, and in line 8 for $\frac{1}{7\cdot5}$ read $\frac{1}{7}$.

THE LEESONA UNIVERSAL ELECTRIC COIL WINDING MACHINES.

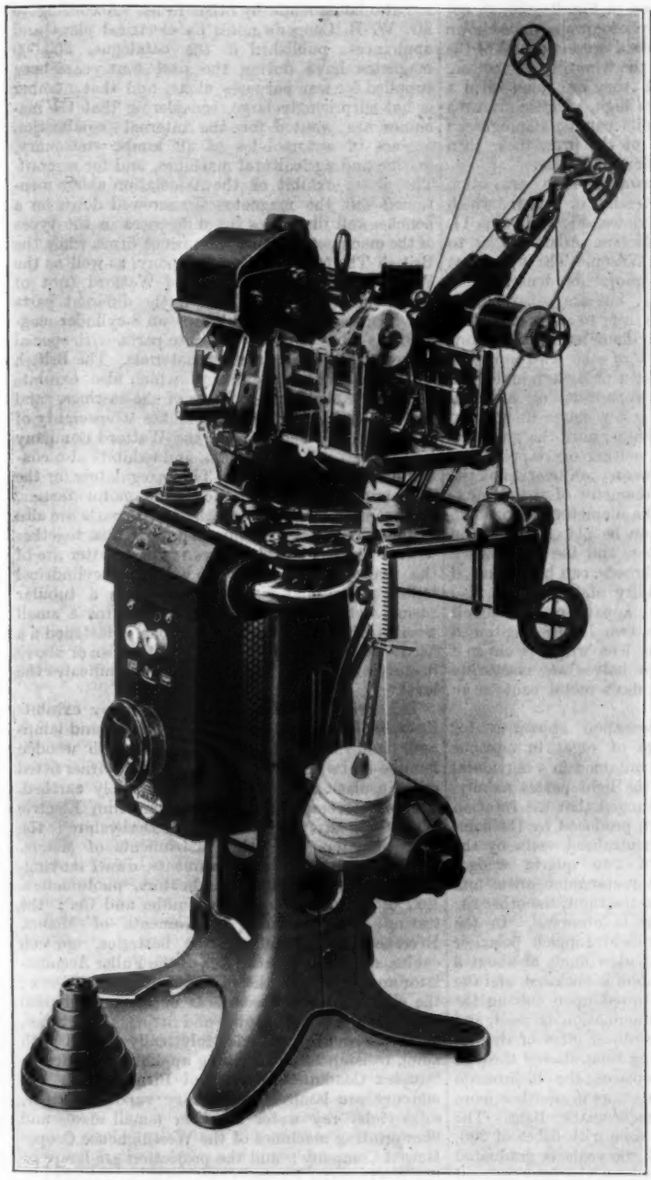


FIG. 4.

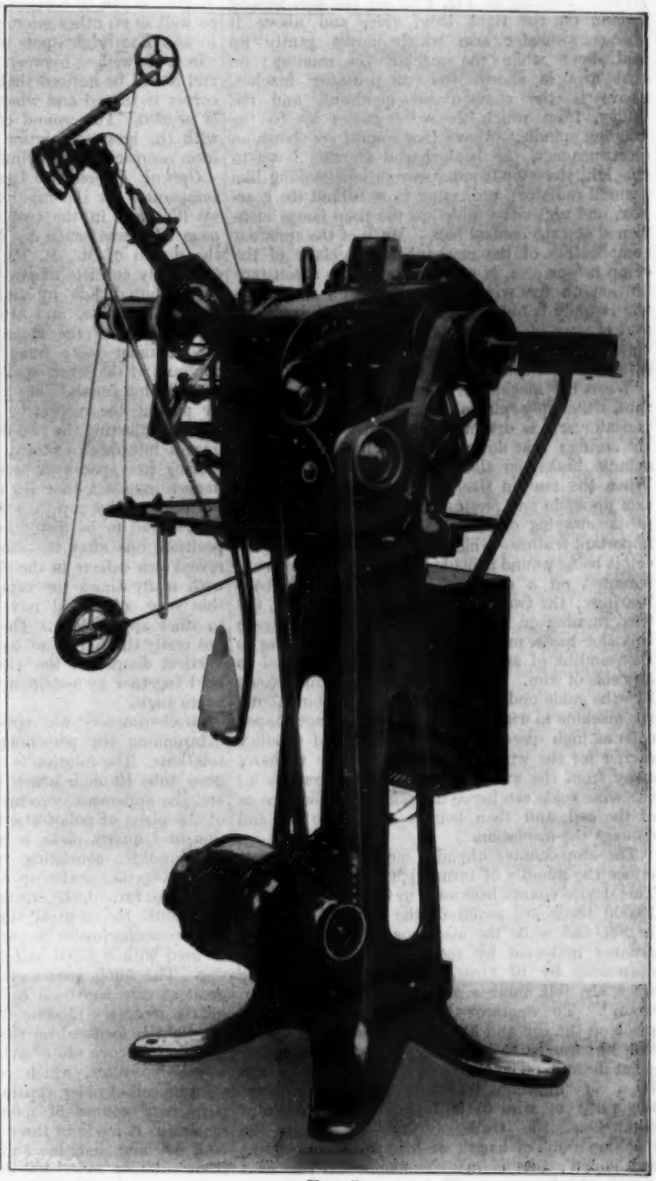


FIG. 5.

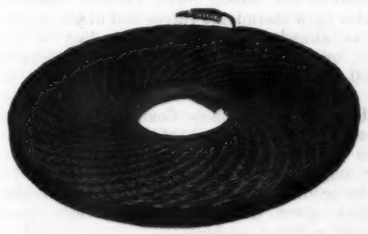


FIG. 6.

FIG. 7.

FIG. 8.

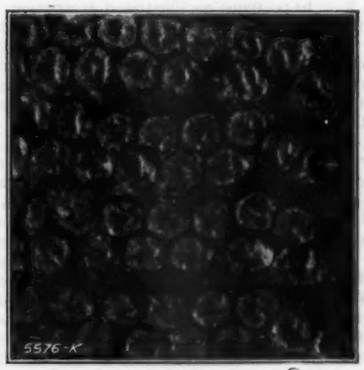


FIG. 9.

a method of cross- or wave-winding, forms self-supporting coils such as the pancake coil illustrated in Fig. 6; No. 96, which winds the wire concentrically on the spindle, interweaving with it at the same time a fine cotton yarn at a different angle to the wire, and which not only provides a wedge form of insulation between the various layers of wire, but also forms insulating checks at the ends of the coil; the coils wound range from $\frac{1}{4}$ in. up to $3\frac{1}{4}$ in. in length and up to 5 in. in diameter (see Figs. 7, 8, 9); No. 98, which winds in the same way as No. 96, but can supply coils up to 12. in. both in length and diameter, and can further wind thick wire coils by the new method of "Gutter" winding. The particulars of our description refer to the No. 96 Leesona, which is illustrated in the photograph Fig. 4, annexed; Fig. 5, also annexed, is a back view of one of the No. 84 type of machine.

The machine, Fig. 4, will wind coils of any wire gauge from 20 S.W.G. up to 47 S.W.G.; it is capable of working at spindle speeds varying from 1,000 r.p.m. to 2,000 r.p.m., and is fitted with automatic fault-detecting devices which stop the machine and indicate the character of the fault by lighting up one of four peep lamps attached to the table in front of the machine, thereby indicating that there is: (1) a knot in the wire; (2) a faulty insulation on the wire; (3) a tangle or too high a tension on the

wire; (4) a break of the yarn. The operator cannot release the brake, which automatically stops the machine, until the fault has been corrected. Looking at Fig. 4 we see the wire-feeding bobbin on the right hand side, and above it the compensator arm which moves gently up and down while the machine is running; on that arm is shown the compensator bracket, above it the compensator quadrant, and the pulley, from which the wire passes on to the winding spindle. Above that spindle are shown an electromagnet, the hook-shaped starting lever to the left, the stop counter-revolution (looking like a small radiator), projecting from behind the gear-box, and under the table are the peep lamps mentioned and the control box. Much of the apparent complication of the mechanism, especially of the compensator arm, is required to ensure a constant tension on the wire. The spindle on which the wire supply bobbin is fixed runs on ball-bearings, and is prevented from rotating by a brake drum (just visible to the left of the bobbin) and pad attached to an arm pivoted on the compensator.

When the machine is started the wire is drawn taut, the supply spindle cannot rotate, and the compensator arm is drawn down against the action of the spring; that downward movement releases the spindle brake, so that the wire feed can start. When the tension slackens the spring moves the arm up again and presses the brake on; hence the gentle swaying of the arm. The wheel—another important feature—which guides the wire while the coil is being wound is made in two halves, which are mounted on a centre spindle running on ball-bearings; the two halves cup into one another, the wire running on the slot between the two edges; this slot has a micrometer adjustment reading to thousandths of an inch, and can be adjusted to any size of wire. The "dogging" mechanism (seen like the guide underneath the supply bobbin) allows the machine to wind rectangular and lozenge-shaped coils at high speeds. It has the form of a pulley carrier for the wire guide which is free to move away from the axis, but cannot move towards it; the wire guide can hence not ride up on the corners of the coil, and then bounce on to the flat and damage the insulation.

The stop-counter already mentioned predetermines the number of turns to be wound on a coil. This device counts backward in tens; hence, when 10,000 turns are required, the counter is set at 10,000, and while the machines is running on the number indicated by the counter is continually decreasing by 10 turns, until the machine stops when the full number required less ten has been wound. The operator then has 10 more turns to place on the coil and he is enabled so to lay on the last 10 turns as to bring the lead wire out at any point desired. The length of the coil is determined by a very ingenious traversing gear, which allows the turns of wire to be laid exactly equidistant throughout the traverse. Coils exceeding the machine limits of length are best wound in sections and joined; this is more economical if part of a coil should burn out. There is also a clock-measuring device which measures the exact length of wire wound on a coil. This is supplied on desire as an accessory; it is useful especially for the experimental stages of winding, the first of a new series. The starting (control) box for the electric motor forms part of the ordinary outfit. The fault-finding devices mentioned comprise relays and rollers; a breaking cotton energises one relay through a switch; the insulated wire passing through two metallic rollers short-circuits these if a portion of the wire should have been left bare; and the two rollers are forced apart against a contact by a kink. In order to facilitate the duplicating of coils of the same or other batches, provision is made that records can be kept of tensions, feeds, &c. The coil wound, it should be stated, is entirely self-supporting, and does not require any support of flanges or head during winding or in use, as the pancake-coil (Fig. 6) shows. When the wire, enamelled or insulated, is wound simultaneously with the cotton, the flanges are built up of cotton during the winding process; whilst the wire convolutions are at right angles to the coil axis, the plane of the cotton strands lies at an angle, and the rate of the cotton-distribution is faster, so that a layer of cotton separates two wire layers from one another. Figs. 7 and 8 show such coils, and the wedge insulation can be recognised in Fig. 9—though not so well as on other micro-photographs since shown to us. The bright spots mark cross-sections of the wires, the wedges between the wire rows are cotton, and it will be noticed that they are thick when a corner is turned and where high electric strength is needed. The wound coils can be impregnated with the igranite solution of the firm, they then form compact strong cylinders or blocks.

Optical Projection Apparatus.—The projection comparator for the rapid testing of screws, which we illustrate in the two views, Figs. 10 and 11, page 249, was made by Messrs. Adam Hilger to the design of Mr. R. P. Wilson. The apparatus essentially consists of two projection lenses which are mounted side by side, but are separable by turning a screw, and are set to approximately the distance of the mean diameter of the screw thread under test; images of the two opposite contours of the screw are then projected, and these images intermesh. The apparatus is adjusted by putting the respective screw gauge in position and by adjusting the two lenses, until the projected images intermesh exactly, neither overlapping nor leaving free spaces in between; an overlap of the images indicates that the diameter of the screw is too large, and a gap that the diameter is too small. The screws to be tested can be placed rapidly in position, one after the other, and the tests which reveal also defects in the threads, can be conducted with many times the rapidity of other methods; this very convenient novel apparatus lends itself to other applications. The two lenses mentioned are really the halves of one lens which is cut in a vertical diameter; the two halves are elastically held together by a strip of sheet metal bent to an acute angle.

Saccharimeters are polarisation apparatus for determining the percentage of sugar in aqueous solutions. The solution is contained in a horizontal glass tube through which the light passes axially, and the apparatus is so arranged that the rotation of the plane of polarisation, produced by the solution in a quartz plate, is neutralised again by the compensator, consisting of two quartz wedges which together make up a rectangular prism and which are turned, the one to the right, the other the left, until the neutral tint is observed. In the Hilger saccharimeter a two-field Lippich polariser is used with a fixed half-shadow angle of about 5 deg. The whole quartz system is enclosed, and the greatest care has been bestowed upon cutting the quartz wedges. Electric illumination is used, and the light is focussed on the object glass of the observing telescope after having been filtered through a gelatine filter, which replaces the bichromate solution cell of older apparatus, as it affords a more permanent source of monochromatic light. The apparatus is made in three sizes with tubes of 200, 400, 600 mm. lengths, and the scale is graduated from -30 up to $+100$ deg. on the international sugar scale; readings can be taken within 0.1 deg. with the aid of a vernier.

We have to postpone an illustrated description of two of the main exhibits of Messrs. A. Hilger, the Abbe and the Pulfrich refractometers. The other exhibits comprise replicas of Rowland's diffraction gratings; graticules, micro-scales and wave length scales produced by grainless photography or by metallic deposition; and a remarkable novelty, multi-coloured graticules for special purposes. These latter had never been produced in this country before the war, and that applies likewise to the aesculine filter and a special light filter, both for aerial photography. These two filters are identical in absorption to some aerial filters of the German army which were recently captured; in keeping qualities and as to absolute consistency of parallelism which the German jelly filters can not maintain, it is said they are considered superior to the German production. One set of trachromatic light filters is also on view. The filters are for autochrome plates, infra-red and ultra-violet; the latter is required, *e.g.*, for reproducing certain wash-drawings painted with pigments like Chinese white.

Magnetos. Insulation.—As regards magneto-electric machines for ignition purposes, it may be stated that nine British firms have combined to form the British Ignition Apparatus Association, and such magnetos are also being made by other firms. According to Mr. W. R. Cooper's notes on electrical plant and appliances, published in the catalogue, 300,000 magnetos have during the past four years been supplied for war purposes alone, and that number is not surprisingly large, considering that the machines are wanted for the internal-combustion engines of automobiles of all kinds, stationary, marine and agricultural machines, and for aircraft The group exhibit of the Association above mentioned—all the magnetos are screwed down on a bench—well illustrates the differences in the types of the machines made by the various firms, while the British Thomson-Houston Company, as well as the Watford Electrical Company, of Watford (not of the Association), further show the different parts of which a magneto is built up—an 8-cylinder magneto has more than 800 separate parts, with special regard also to the insulating materials. The British Thomson-Houston Company, which also exhibits aluminium alloys in the forms of die-castings, sand castings and brass pressings, makes a speciality of insulating silk and paper; the Watford Company largely uses mica insulation, and exhibits also control pillars for arc furnaces, Thury regulators for the same purpose and automatic electric-motor starters. High-tension magnetos and their spare parts are also exhibited by Messrs. Simms Motor Units, together with magnetic petrol gauges. These latter are of the hydrometer float type, with long cylindrical bulb; as the float rises, sometimes in a tubular casing, which may be slotted, it turns a small wooden disc to which an iron bar is fastened; a needle magnet mounted in front of the disc or above it moves in unison with the bar and indicates the level.

The British Central Electric Company exhibits fuses, wall-plugs and also shock-proof hand-lamps and hand-shield adapters, provided with wooden handles and wire caps; the live parts are either fitted with insulating protection or are visibly earthed. The silk-covered wires of the Concordin Electric Wire Company, of New Sawley, Derbyshire; the potentiometers and other instruments of Messrs. Crompton; the varied instruments, dwarf moving-coil ammeters, frequency indicators, photometers, &c., of Messrs. Everett, Edgcumbe and Co.; the testing and measuring instruments of Messrs. Evershed and Vignoles; the batteries, ignition cables, steering indicator, &c., of the Fuller Accumulator and Carbon Works, of Chadwell Heath, Essex; the sliding-contact resistances of Messrs. Isenthal and Co.; the Simplex tubes and fittings (steel tubes, acetylene welded and electrolytically coated with zinc), resistances and cooking appliances of Messrs. Simplex Conduits, Limited, of Birmingham; the mercury arc lamps and mercury vapour rectifier, ultra-violet ray water steriliser (small size), and blue-printing machines of the Westinghouse Cooper Hewitt Company; and the projection arc-lamps of the Westminster Engineering Company, do not call for special notice. Tungsten lamps are mainly exhibited by the Edison Swan Electric Company, who also show thermionic valves and other specialities, as already mentioned. According to Mr. Cooper, one firm alone is now exporting between 600,000 m. and 700,000 m. of tungsten wire per week to foreign markets. The exhibits of the Rapid Magnetting-Machine Company, of Birmingham, consists of photographs of the Rapid Thompson Davies electromagnetic ore separator for treating feebly magnetic ores (monazite sand, wolfram-tin) and the products obtained. The Electric Welding Company gives demonstration of their hand-automatic welding machine.

Passing to insulating compounds, in which noteworthy progress is marked by Sir Robert Hadfield's "stallog"—remarkable for its low electric loss—we notice the varnished cambrics and silks (Abbott brand), in yellow, brown and black, of Messrs. Abbott, Anderson and Abbott. The "formite" of the Diamond Lacquer Company, of Birmingham, is in its original form a resin, melting-point 150 deg. F., which is soluble in alcohol, acetone, and fusil oil, giving a varnish. At 250 deg. F. formite changes into a hard, amberlike substance, which is

OPTICAL PROJECTION COMPARATOR FOR TESTING SCREW-THREADS.

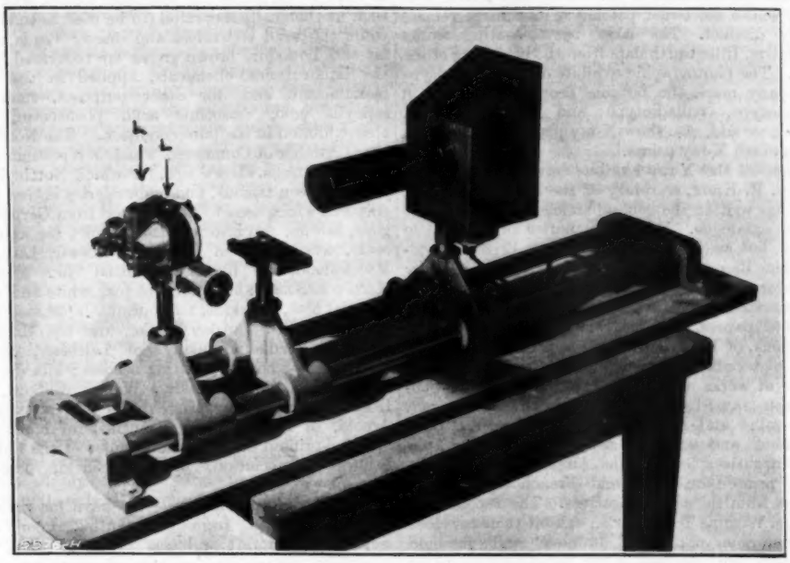


FIG. 10.

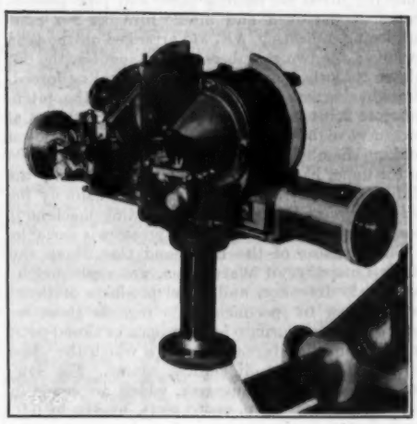


FIG. 11.

used in the place of amber, ebonite, &c., in the form of a moulding mixture or a powder; these features remind us of the properties of bakelite. The "erinoid" of Erinoid, Limited, is a plastic material, described as non-inflammable, odourless, a good insulator and an ideal material for turning, which can be drilled, dyed, &c. The black plastic composition of the Improved Solidite Company is recommended for moulded insulated articles as a substitute for ebonite.

The "high-tensite" exhibited by the Park Royal Engineering Works, N.W. 10, is made by High-Tensite, Limited, Normandy Street, E. 16. It is a chocolate-coloured product which is described as non-hygroscopic, non-inflammable, and as having a dielectric strength of 20,000 volts per millimetre thickness; it does not carbonise under sparking and it is claimed to have a wearing surface equal to that of brass. The Micanite and Insulators Company, E. 17, make their "paxolin" of layers of paper impregnated with the condensation products of phenol and formaldehyde; the product is shown in sheets, plates, cylinders ($\frac{1}{2}$ in. wall thickness), &c., and the exhibits exemplify that paxolin can be drilled, sawn, turned, &c. The "Empire" insulator of the firm is oil-cloth or paper, and a good display is finally made of micanite in foil, tubes, cloth, tape, and rings, &c.

Before passing on to paper and textiles, which ought to follow insulating materials, we may revert to measuring machines and physical apparatus from which we had drifted.

Measuring Mechanical and Physical Instruments.—Commenting, in his article contributed to the exhibition catalogue, on the development of measuring and mechanical instruments, Mr. Douglas T. Heap remarks that the future can not be foretold at present. The demand for sets of reference and workshop gauges and for precision instruments and recording apparatus has been so large during the war, that the available output at first fell far short of the requirements and the demand for instruments and gauges for the general engineering trade cannot yet be met by British makers. Thanks to very special efforts, however, the output of gauges and scientific instruments for the Government departments has been enormous, and the requirements are now being fairly satisfied. As to general conditions, Mr. Heap would develop a good line of standard instruments and recorders rather than hasten bulk production, and he directs attention to the fact that whilst the users of mechanical instruments (gauges, micrometers, &c.) are fully alive now to their advantages and limitations, the staff is frequently not encouraged to make use of the facilities afforded by good instruments for ascertaining the conditions of the plant—a state of affairs no doubt partly due to the lack of scientific training.

The display of instruments at the exhibition, though necessarily inadequate, is comprehensive in many respects and instructive. The National Physical Laboratory very properly takes the lead with its numerous appliances, and both the Engineering and the Metrology Department have contributed to the collection. As we have during the last few weeks illustrated a number of their novel machines, we reserve for a future occasion a description of the mirror extensometer of the Engineering Department, which reads within 1–250,000 in., by the aid of which the modulus of elasticity of a copper wire, 0·05 in. in diameter, has been obtained in a gauge length of only 3 in. The other exhibits of the Laboratory comprise a model and photograph of Mr. Campbell's standard of mutual inductance balance, the Kelvin double bridge, Weston normal cells, and ships' models from the Tank Department.

The Meteorological Office also has prepared a very instructive exhibit. The rubber pilot balloons (filled with hydrogen) are intended to rise to heights of 10 km., 20 km. or 30 km. and more, until they burst and drop, the diminutive meteorograph records of air pressure and temperature being generally secured intact. On one record obtained there was no change of temperature in the isothermal layer from 10 km. up to the maximum height reached, 37 km. Balloons are also used in determining the velocity and directions of air currents up to heights of 10 km., and the exhibits explain the ingenious apparatus used and their calibration.

Sir W. H. Bailey and Son, Salford, show tell-tale pressure gauges, oil testers, speed indicators, and Mr. H. M. Budgett, of Chelmsford, exhibits true plane steel surfaces for optical and engineering work, flat-end gauges, also of the Johannsson style, and an exact model of a setting-out table, 6 ft. by 4 ft., exemplifying three-toe support, &c. There is also a bevelled straight-edge of steel resting on six pillars, each exactly of 1 in. height, but all made up of different numbers of separate flat plate gauges wrung together. Among the slide-rules and time-saving calculators of Messrs. John Davis and Son, of Derby, we notice the Smith-Davis piecework balance calculator, a wheel, about 3 ft. in diameter, on the rim of which the wages due to any of the men engaged on the same contract, can be seen, and the Davis-Horsman premium calculator which gives the percentage difference between time allowed and hours taken. Mr. W. H. Harling exhibits the Empire sets of drawing instruments, designed by the Ministry of Munitions. Some of the screw gauges of Messrs. Horstmann Company, Limited, are glass hard. The chemical balances, now with aluminium-alloy beams, of Mr. Oertling, are well known, as are the decimal micrometer caliper gauges ("Ciceri-met") of Mr. J. Ciceri Smith. The manifold exhibits of Messrs. Vickers, which should have been mentioned before, comprise duralumin, heavy drop-forged stampings, high-speed tools including twisted drills of vanadium steels, Vickers' reamers, quick-change drill chucks, magneto machines, Vickers' hardness comparator (a pocket Brinell apparatus), and plug-screw gauges produced by non-skilled labour by a special grinding process.

Of Dr. E. E. Fournier d'Albe's optophone, which we described on page 133 of our issue of February 9, 1917,* we will only say that the instrument is now made by Mr. W. Forster Brown, and that at a demonstration lecture given last week a blind lady was able to read some words of a book, the page of which had been selected by the chairman, Professor Gregory. The book is placed on a glass frame, the print facing downward; by turning a handle the reader moves the apparatus underneath the frame to the right or left following the lines of the print, and turning back when necessary; the type of the book was a little bigger than our own.

Calorimeters, Autoclaves, Furnaces, Lamps.—The Mahler-Cook bomb calorimeter of Messrs. C. W. Cook, Manchester, their Curnon recording steam meter; the high-pressure hydraulic pump designed by Professor Petavel, for producing pressures from 500 lb. up to 30 tons per square inch (a hand pump, of nickel-chrome steel); an autoclave for pressures of 200 atmospheres and temperatures of 350 deg. C. and various other apparatus, bring us back to physical apparatus. All the autoclaves shown by Messrs. Baird and Tablock, E.C. 1, and other firms, for chemical reactions and for food preparation, are of the clamped or screwed-down cover type; we have not noticed any automatic devices like that of Mr. Lennox which we illustrated in our issue of August 9, last. The Wild-Barfield furnaces of the Automatic and Electric Furnaces, Limited, were also recently noticed. The Davis Furnace Company, of Luton, show their portable tool-makers' outfit with air blast burners, blowpipes, smith's hearth, laboratory crucibles, &c. Messrs. Fletcher, Russell and Co., of Warrington, make a show of improved Bunsen burners, palatine burners, ring burners, and blowpipes. The furnaces of Mr. A. Hermansen, of Birmingham, are for melting glass and metals; they were described by Mr. T. Teisen before the Institute of Metals in 1917.†

The heat-regulator of the white-metal melting

* See also pages 359 and 384 of volume ciii.
† See ENGINEERING, vol. ciii., p. 315.

and other furnaces of the Monometer Manufacturing Company, of Aston, Birmingham, has been described in our columns. The lead-melting furnaces are specially fitted for feeding cable and pipe presses. Some of the oven and muffle furnaces for case-hardening, reheating, &c., are arranged on the twin system; the two chambers are rectangular, the one above the other, and heated by natural or forced-draught burners, gas or fuel oil, *e.g.*, the pitch-creosote 2.B.4 mixture; town gas can be burnt at pressures of 5 lb. per square inch. In the lower soaking chamber the temperature rises to 800 deg. C., in the upper hardening chamber to 13·50 deg.; the sliding doors of the furnace fronts are shut by the aid of pairs of levers. The die-casting machine is heated by a Bunsen burner; the pressure is variable.

The furnaces of the Richmond Gas Stove and Meter Company, of Warrington, are explained by large-scale drawings, and novel products of theirs are on view in specimens. As regards glass, we notice a melting furnace for four open or closed pots, and an annealing furnace, through which the glass is carried in trays on endless chains. The low-pressure gas and air furnaces, which are made in sizes from 9 in. by 12 in. up to 30 ft. by 8 ft. by 6 ft. for tool-steel hardening, annealing, &c., work under fan draught in an oxidising or reducing atmosphere with preheated air; the wire-annealing furnaces are coke-heated. The specimens of cooker linings, crown plates, pastry boards, reflectors, &c., are all leadless; the coloured lamp reflectors are covered first with white enamel, and then with a clear glaze which may contain lead. Paper weights, pin trays, &c., are made of cast-iron and enamelled and coloured by the dust-on process when red hot, the enamel being applied in dry powder through a suitable duster; heating to 950 deg. C. may be required for 5 minutes or 10 minutes. The furnaces of the Watford Electric Company have already been mentioned. As regards lamps we should state that the combustion-tube oil lamps of Messrs. Ackroyd and Best, of Morley, near Leeds, are of the "Hailwas" patent; the combustion tube and inner glass replace the inner gauze. The heat-resisting glass of the lamp for miners is described as of the "Hailwas" brand. The Bland gas burners of the Bland Light Syndicate are Bunsen tubes of porcelain combined with nozzles; and the "shells"—the name indicates the shape—covering the metal holders of inverted gas mantles are also of Bland porcelain; burners of 300 candles and three-light burners of these high-power low-pressure lamps are on view. High-power oil lamps are also exhibited by Blanchard Lamps, Limited.

Photography. X-Ray Apparatus.—The main advance in photography has been in developers and in dyes for sensitising and for making colour filters, and much of the credit is due to Professor W. J. Pope, working in conjunction with Dr. W. H. Mills, of Cambridge, and with Mr. C. S. Gibson, of Messrs. Ilford. The chief chemicals needed were metol, amidol, glycin, scalol, hydroquinone, and pyrogallic acid, the sensitisers pinacyanol (sensitol red), pina verdol (sensitol green) and the new sensitol violet, which is remarkably useful. All these sensitisers and also other dyestuffs, erythrosine, fluorescein, crystal violet, tartrazine, acridine orange, and methylene blue are instructively displayed by Messrs. Ilford; there are further light filters, three-colour sets, compensating filters for autrochromatic and panchromatic plates, and colour-contrast filters and also panchromatic plates themselves, made by a new process. The photographic chemicals, above mentioned, which like the dyes were German specialities, are now made by Messrs. Johnson and Son, who also exhibit silver proteinate (medicinal) and molybdic acid and ammonium molybdate for steel analysis. The third firm of photographic exhibitors, Messrs. T. Illingworth and Co., have their share in another line of advance of which the war picture facing the visitor who enters the exhibition, gives evidence; the progress concerns the remarkable enlargements of photographs. The dimensions of the photograph are 12 ft. by 2½ ft.; the paper was made by Messrs. Wiggins, Teape and Co., the bromide film is due to Messrs. Illingworth, and the actual photograph was taken by Messrs. Raines and Co., of Ealing. Another photograph, made by Messrs. Raines', we see from Mr. Chapman Jones' catalogue article, measures 23½ ft. by 13½ ft., being a 100-fold enlargement of a negative of 3 in. by 2½ in.; the grain of the paper becomes so diffused in the enlargement, that it is lost, whilst the larger patches of the image remain fairly distinct. The large baryta-coating works of Messrs. Illingworth date from the beginning of the war. The photographic exhibits of the Platinotype Company mark the notable progress achieved in platinotype, palladiotype and satista. Messrs. Ilford, we add, also show X-ray plates; and Messrs. Illingworth X-ray prints.

Some of the X-ray exhibits have been arranged by Dr. R. Knox, secretary of the Röntgen Society, who has written the general article on Radiography in the catalogue. We cannot notice this branch in detail, but we should mention that a British Photographic Research Association has quite recently been formed by scientists and manufacturers.

Paper Textiles.—Of the two chief firms in photographic papers, the one, Messrs. Alexander Pirie and Sons, of Bucksburn, Aberdeenshire, exhibit the raw materials for paper manufacture in general, views of works and machinery, the products (photograph raw base paper, baryta-coated paper, ferro-gallic and ferro-prussiate raw paper, "true-to-scale" and sectional raw paper), photographs from negatives lent by the Air Ministry, and pictures printed on Pirie, and French and German papers from the same negatives. The second firm Messrs. Wiggins Teape & Co., exhibit their raw base photographic paper for bromide and gas-light emulsion, and samples of the baryta-coated paper and many varied specimens of finished prints. Filter papers for the chemist, some varieties of which were only taken up in 1914, are exhibited by Messrs. Evans, Adlard & Co., of the Postlip Mills, Gloucestershire, Messrs. W. & R. Balston, of Maidstone (Whatman papers) and Messrs. J. Barcham Green & Son, of Maidstone. Messrs. J. Spicer & Sons, show photo-mount papers, but their interesting specialities are the waterproof-fibres and imitation vegetable parchments used in the production of waders (to be worn inside the boots), socks, jackets, waistcoats, wallets, towels, boot-laces, string, drinking cups, food containers, ivory cards, &c. The Textile Engineering Company have another novel speciality with which the war has familiarised us, paper yarn of all descriptions in twine, cloth for bags, matting for stair carpets, wall coverings of pure paper and of mixture, bags for grain, fertilisers, cement, &c.; all these wares are made by the Company's own machinery.

Cellulose Acetate.—The cellulose acetate of the British Cellulose and Manufacturing Co., about which so much has been said of late, is not in any sense a new product, of course. It has long been known that cellulose from wood pulp and other sources is converted into a white amorphous mass when treated with acetic acid anhydride at 180 deg. C., and that this mass is soluble in more of the acid, and further in acetone and other reagents, and then dries to a transparent film which resembles collodion (the solution of gun cotton in ether-alcohol), but is non-inflammable. The cellulose acetate is a valuable material for making varnishes, camphor substitutes and other chemicals, and especially for aeroplane dopes; the films may replace collodion films in kinema work and also windows. The firm exhibits acetate in large rolled-up sheets, in films on wire netting, and coloured with aluminium or blue, red, khaki, aluminium, &c., with pigments in emulsions; samples of reagents used in its preparation (as solvents) and utilisation, methylacetate, triacetine, benzylalcohol, tricresyl phosphate and triphenyl phosphate (a crystalline solid) are also on view.

In briefly reviewing in the catalogue the great inventions made in this country during the past two centuries in the textile industry, to which the country owes so much of her commanding position in the world's markets, Mr. A. E. J. Brookes, of Manchester University, points out that the future of the industry depends upon further strenuous study and scientific and artistic instruction. We mention, in the first instance, the exhibits of the Bradford Technical College, which demonstrate in particular the manufacture of worsted, in which Germany excelled, and the use of oil emulsions in textiles. The Bradford Wool Extracting Company explains by samples the wool carbonising process; the raw wool is washed, steeped in acid and heated in order to carbonise the vegetable matter which is then mechanically separated (to be used as manure) while the wool is washed and dried; crude wool fat and Yorkshire brown grease are recovered from the liquor; fine chemicals, applied in the dye manufacture and for other purposes, such as salicylic acid, cresotinic acid, phenacetin, are also exhibited in the pure condition. The Nottingham Chamber of Commerce, which is represented in several sections, shows lace, for which Nottingham has long been famous, and embroideries on net and guipures which used to be imported from Germany, glove fabrics, and also in artificial silk; the knitted coats, wraps, &c., of Messrs Neckwear, Ltd., of Macclesfield, are likewise artificial silk. Messrs. Martin & Sons exhibit furs, in fox, white and red, celestial blue, sealskins, and musquash (dressed and dyed). Messrs. Tansley & Co., and the Hosiery Machine Needle Company, of Leicester, make specialities of hosiery knitting needles; silk dyeing is the speciality of Messrs. Walker & Sons, of Leicester, and silk ware is exhibited by Messrs, J. Arnold, of Macclesfield. The tasteful hand-and machine-printed cretonnes and voiles of the Calico Printers' Association, of Macclesfield, deserve particular mention.

Aircraft and Gas Traction.—We have for various reasons refrained from commenting upon the sections of Aircraft and Gas Traction. The remarkably instructive aircraft display, towards which most visitors directed their steps in the first instance, was arranged by the Aeronautical Inspection Department, and is only mentioned in the final edition of the catalogue; the Gas Traction Committee, appointed in November, 1917, is responsible for the gas traction exhibits. Publicity in such matters is restricted, but we hope to deal with novelties in these branches on special occasions.

Miscellanea and Addenda.—Messrs. Rheinberg draw our attention to the fact that in their grainless photography graticules the glass is coated with a thin film of collodion (not celluloid, as we had written). We cannot notice the sections on Food Production, on Surgical, Bacteriological and Pathological Appliances, and on Illustration and Typography, though they contain much of interest. The section on Exploitation of British Natural Products contains the ore collections of the Geological Survey and Museum and of various exhibitors, and is not confined to the United Kingdom, of course. The British Litho-stone Company has only one exhibit, a slab 4 in. thick, 2 ft. 8 in. square, slate-blue in colour; 10,000 tons of litho-stones used to be imported yearly from Germany. The soda of the Magadi Soda Company is pure trona, Na_2CO_3. $NaHCO_3.2H_2O$, free of sulphur, coming from the Magada Lake in British East Africa, situated about 400 miles inland from Mombasa. The lake has an area of 30 sq. miles, and powerful sources continuously replenish the soda deposits. The oils of the British Oil and Cake Mills, Limited, another exhibit, are chiefly of three groups—the palm kernel, the coconut and the ground nut. The standard paste from natural indigo exhibited by the Indian Planters' Association is the outcome of researches by Professor H. E. Armstrong and Mr. Reginald Brown, and is used by woollen dyers for producing the naval blue. The attractive exhibit of Mrs. Grieves's British Medicinal Herb School, of Chalfont St. Peter, mentioned in the same section of the catalogue, should not be overlooked, nor should the seed-testing incubators of Messrs. C. Hearson & Co. All seeds, we understand, are now to be tested in electrically-heated ovens, wet and dry, in the light or dark, for their germinating power; the tests may take from three to 10 days and more.

Passing to addenda we notice the pure dyestuffs from coal tar, exhibited by Professor E. Knecht, of Manchester; the fine chemicals of Messrs. Pierson, Mirrell & Co., of Barnet (salicylic acid, phenacetin and also galvasol), recommended for addition to electrolytic zinc baths); the hydroxylamine and hydrazine sulphate (powerful reducing agents), chromic acid, &c. of Messrs. Thomas Morson & Son; the essential

oils of Messrs. Stafford, Allen & Sons; and the "starch-all" of Mr. M. Emanuel, a substitute for starch, looking like a white precipitate of some alkaline earth in water. We finally revert to the interesting intermediate products of the United Alkali Company, briefly mentioned in our first article. The acetic acid and its chlorine derivatives find wide application. Benzyl alcohol is the base for the indigo manufacture, dinitrochlorbenzol the base for cotton blacks; the nitrophenols are converted into picric acid; phthalic anhydride serves for the preparation of eosine and other sensitisers.

The most interesting novelty shown by the United Alkali Company is the "duroprene," a rubber derivative which Mr. J. S. Peachie, of Manchester, University, obtained by the action of chlorine on rubber. Duroprene looks a plastic mass somewhat like rubber, but two-thirds of its weight is made up of chlorine. In spite of that high percentage of chlorine it seems to be one of the most stable and indifferent compounds known; it is indestructible by acid, not attacked by *aqua regia* even, and dissolved in solvent naphtha, it may be applied to all kinds of substances, iron included, to form a fairly incorrodible coating. There is little incentive on this side of the Channel to follow up the synthetic study of rubber, apart from the undoubtedly high theoretical interest of the problem, considering the plentiful supply of rubber which was secured before the war; there is all the more promise for a rubber derivative like duroprene.

Concluding Remarks.—The Exhibition has to be closed to-morrow, Saturday, because King's College cannot spare the rooms any longer. The attendances and the general feeling of satisfaction would have justified a prolongation. In spite of the absence of the "shop" element, possibly because of that absence, the Exhibition has been a decided success, and that not only in the sense that the promoters intended it to be, to foster the application by the manufacturer of scientific methods in a country where neither the knowledge nor the enterprise are lacking, but also from the commercial point of view. The success has put a very heavy burden of work on the organising committee, and especially on its chairman and secretary, Professor R. A. Gregory and Mr. F. S. Spiers, B.Sc. There is a widespread impression that the Exhibition is a kind of successor to the Board of Trade Fairs—one of which closed last week at Glasgow—and that the authorities have borne the risk and expense, or contributed largely to the funds at any rate. That is entirely erroneous. Apart from the remarkable display of the Air Ministry, and some exhibits by the Munitions Inventions Departments and some other optical departments, the authorities have not supported nor assisted the committee in any way, except that the Board of Trade boomed some cases. The financial burden falls altogether on the British Science Guild and the donors. The expenditure, we understand, is expected to remain below 5,000*l.*, which is a remarkably low figure in the annals of Exhibitions. No charge was made for space. It is in a way satisfactory—though it did not facilitate the tasks of the committee or of the writer—that several exhibitors profited by seeing the more scientific display of their fellows and rearranged their exhibits, in many cases adding to them; further exhibitors came in, too. A third edition of the catalogue—issued at 2*s.* 6*d.*, which does not cover the cost of its production, we may say—had hence to be issued; the subject-matter index which it embodies will make the catalogue more valuable for future reference. Three hundred firms took part in the Exhibition, and the number of paying visitors passing the turnstiles exceeded a thousand on the Saturday afternoons.

A STATE DIRECTORY OF BRITISH AND IRISH MANUFACTURES.—*The Board of Trade Journal* states that an index or director of British and Irish manufacturers is in process of compilation by the Department of Overseas Trade for official use only in the Department and by His Majesty's Trade Commissioners, Consular officers, and other correspondents of the department abroad in dealing with inquiries which they frequently receive for the names of makers or suppliers of goods in this country for delivery either now or after the war. Further information as regards its objects and scope can be obtained by application to Department of Overseas Trade (Development and Intelligence), 73, Basinghall street, E.C. 2.

PUMPING ENGINES FOR THE CAIRO MAIN DRAINAGE.

THE pumping station for the new main drainage system of the City of Cairo, is situated at Kafr-el-Gamous, approximately 8½ miles from the city, and the whole of the drainage flows through a main collector or culvert some 14,800 yards in length, extending from the city into the suction sump situated immediately below the engine room at the pumping station. In the present article, we do not propose to refer to the purely civil engineering side of the scheme sewage, although this contains many features of great interest,* but to deal only with the mechanical equipment of the main pumping station, and more particularly with the main pumping engines themselves.

The machinery at the main pumping station consists briefly of four sets of inverted vertical quadruple expansion pumping engines, each driving direct from the engine cross-heads a set of triplex single acting plunger pumps. In addition to the main engines, the station contains three direct coupled generators for supplying light and power to the pumping station and adjacent buildings, also the necessary auxiliary machinery for the supply of both filtered and unfiltered water, condensing plant, &c. Steam is supplied to the whole of the engines from four Babcock and Wilcox water-tube boilers.

The main pumping engines with which we are now dealing contain several novel features, designed to secure extreme economy of steam, which renders them of considerable interest to all concerned in the performance of highly economical pumping machinery. These engines, of which a general view is given in Fig. 1, on page 260, were designed and built by Messrs. James Simpson and Co., Limited (now Messrs. Worthington-Simpson, Limited), of London and Newark, who were the contractors for the whole of the pumping machinery, to meet the specification of Mr. Charles Carkeet James, M.Inst.C.E., Controller-General of the Main Drainage Scheme to the Egyptian Government.

This specification called for engines of the inverted vertical quadruple expansion type, to work with steam at 200 lb. pressure superheated to 180 deg. F., and in view of the excessive cost of fuel, the greatest stress was laid upon the securing of great economy in the consumption of coal. To meet the demands of this specification, Messrs. Simpson constructed the engines illustrated by the engravings on Plate XX, published with the present issue.

The engines may be briefly described as being of the inverted vertical quadruple expansion three-crank type, having the high and first intermediate cylinders placed tandem over the centre crank, and the second intermediate and low-pressure cylinders placed one on either side of the first intermediate cylinder and over the outer cranks, as shown in Figs. 2 and 3, on Plate XX. The chief point of interest with regard to the steam end of the engines lies in the arrangement of the high and first intermediate cylinders, which, as will be seen from Fig. 5, Plate XX, are each single acting.

There are numerous points in connection with this arrangement which are claimed as advantages over the more usual plan of providing two super-imposed double-acting cylinders, among others being the very considerable reduction in the number of valves and their consequent working parts, which tends towards a reduction in steam leakage and increased mechanical efficiency. There is also a reduction in the over-all height of the engine, and a simple and secure base is obtained for the high-pressure cylinder, thereby ensuring freedom from vibration and consequent wear on the working parts of that cylinder and its gear. Further, there is an entire elimination of the gland and stuffing-box on the high-pressure cylinder, which the usual double-acting construction would require, and which with steam at such high pressure and temperature would tend to be a source of trouble due to scoring of the piston rod and consequent steam leakage.

The arrangement, in fact, is practically the equivalent of one double-acting cylinder as far as the number of valves and amount of valve gear is concerned, with the advantage of a reduced temperature range in each cylinder. The pistons of the two cylinders are, as will be seen from Fig. 5, in one piece, forming what may be called a differential piston. The upper part of this piston is in plunger form, and fills the high-pressure cylinder for the whole length of the stroke, thus preventing the cooling of the high-pressure cylinder walls by contact with the lower temperature steam contained in the annular space in the upper part of the first-intermediate cylinder. This annular space is connected by means of the pipe marked "equilibrium pipe" in Fig. 4, Plate XX, with the low-pressure receiver; any leakage past the piston of the single-acting cylinders being thus employed to do useful work in the low-pressure cylinder.

The steam cylinders are respectively 17 in., 27 in., 33 in., and 49 in. in diam. with a common stroke of 36 in., and when running at the normal speed of 22 r.p.m., each engine is capable of developing 200 h.p. The high and first-intermediate pressure cylinders are fitted with double beat drop valves, the period of opening on the steam valves of both these cylinders being under the control of the governor, while the second intermediate and low pressure cylinders are fitted with Corliss valves, the period of opening on the steam valves of these cylinders being adjustable by hand, while the engine is in motion.

The whole of the valves are actuated by a lay shaft carried along the front of the cylinders, this shaft being rotated at the same speed as the crank shaft through skew gearing carried on a vertical shaft reaching from the crankshaft to the valve motion lay shaft. The vertical shaft just referred to can be seen on Fig. 2, between the centre and right-hand cranks. By the use of the lay-shaft, the necessity for heavy eccentrics, rods and rocking levers is dispensed with and the power absorbed in actuating the valves is reduced to a minimum. The whole of the actuating mechanism of the valve gear is enclosed within oil-tight casings carried on the cylinders, so that this mechanism is enabled to work immersed in oil. The steam valves of all cylinders are fitted with a trip motion, giving practically instantaneous closing, the shock on the drop valves being absorbed by oil cataract dashpots to ensure silent working, while the Corliss valves are controlled by spring dashpots of the usual type. The exhaust valves throughout are controlled by positive motion gear. The arrangement of the valves and trip motion for the high-pressure and first-intermediate cylinders, is shown in Fig. 5, while Figs. 6 and 7 respectively show the high-pressure steam valve and the first intermediate cylinder exhaust valve to a larger scale. The arrangement of the Corliss valves is shown in Fig. 8.

Owing to the type of link mechanism adopted, for actuating the valves, the distortion due to obliquity of the usual eccentric gear is practically non-existent this was found to be a distinct advantage in adjusting the valve motion relatively to the actual working steam pressures, owing to the somewhat unusual differences in pressure between the upper and lower ends of the two final cylinders, due to the fact of the first two cylinders being single acting. In order to equalise the pressures, and avoid the loss due to "drop" between succeeding cylinders, reheater receivers of ample proportion are provided, these are fitted with solid-drawn steel tubes, and are coupled to the jacket system, so that steam at initial pressure and temperature is continually circulated through the tubes, thereby drying and reheating the working steam on its passage to the succeeding cylinder.

The governor is of the vertical type, having the whole of the working parts totally enclosed, and to provide for the very wide range of speed called for in the specification, viz., from 10 r.p.m. to 30 r.p.m., the counterweight is in the form of a "water balance," arrangements being provided so that water may be admitted to or withdrawn from the floating tank forming the balance weight by means of regulating valves, until the desired speed of rotation is obtained, when the regulating valves are closed and the speed of the engine is maintained constant until it is again desired to change it by manipulation of the regulating valves.

The jackets are supplied with steam on the "closed continuous" system, the steam entering at the high-pressure cylinder jacket, and passing successively through the remaining cylinder jackets and reheater tubes, until the whole of the steam condensed is trapped off below the low-pressure jackets, and thence returned to the boilers by the jacket water pump.

The main framing and crank connecting-rod motion of the engines is of the usual open-fronted marine design, and calls for no special comment, the main features being clearly illustrated in Figs. 2 and 3. Lubrication is provided by a continuous gravity system from a tank located on the top platform, from whence the oil is led by gravity to all rubbing surfaces and working parts, each having its separate control, The surplus oil is caught by drip trays and led to a filter located below the engine-house floor, where filtration and separation of entrained water are performed, the filtered oil being then automatically returned to the overhead supply tank by the lubricating oil pump.

The main pumps, as already stated, are of the single acting plunger type, and are located on the pump floor 27 ft. below the engine-house floor. The plungers are 21½ in. diam., and each is coupled to the yoke of its own engine cross-head by four steel rods. The plungers are of chilled cast-iron ground dead true, and the stuffing boxes are fitted with lantern rings, through which clean water is forced to prevent grit and abrasive particles being drawn into the packing, and thus causing scoring and wear. The glands are fitted with rack and

* An excellent account of this scheme is given in a paper entitled "The Main Drainage of Cairo," by Mr. Carkeet James, read before the Institution of Civil Engineers in February, 1916.

pinion gear for tightening the packing to ensure the gland being kept accurately lineable with the plunger and so avoid friction. The pump cases are built up of massive castings, having ample dimensions in all directions, and of simple form, so as to avoid the formation of casting stresses or unequal strains in working.

The pump valves are of the rectangular leather-faced flap pattern, which from long experience have been proved most effective when dealing with sewage, especially of the nature met with in Eastern countries which is invariably heavily charged with road detritus and small solids carried in suspension. For this reason also the total valve area is proportioned on a most liberal scale, the valves covering the entire ends of the plunger chambers. All pipes leading to and from the pumps are of large diameter, and bends are formed with specially large radii, so as to prevent deposit and consequent fouling within the pumps.

Manholes, ample in number and size, are provided for access and cleansing the interior when occasion demands, and air vessels of large capacity are provided on both suction and delivery sides to absorb shock and ensure a steady flow. Non-return valves are fitted immediately adjoining the main outlet on each pump and sluice valves controlling the delivery from each pump, are located in a valve pit immediately outside the engine house. In the same pit is located a sluice valve for closing the rising main, should it become necessary at any time to entirely isolate the pumps from this main.

Into the rising main is fitted a recording "Venturi" meter, the recording apparatus being located in a meter house some little distance from the engine room. By this means a continual check is provided upon the performance of the pumps and any drop in volumetric efficiency is at once detected.

The condensers are of the usual tubular surface pattern, located in a gallery running the entire length of the engine-room, at the back of the main engines and situated about midway between the engine-house and pump floors. The exhaust steam is passed through one of the Messrs. Simpson's patent oil separators on its way to the condensers, to ensure the separation of entrained oil, and thus prevent fouling of the condenser tubes.

The air and circulating pumps are located on a stage somewhat lower than the condenser gallery and are driven direct from the centre and one of the end main pumps respectively by return plunger rods. Above the third main pump plunger are located the feed, air charging, jacket water and lubricating oil pumps so that each engine when in operation is entirely self-contained and independent of auxiliary help of any kind.

Each engine crankshaft is fitted with two flywheels of ample diameter and weight to keep the engine steady at the lowest specified speed, viz., 10 r.p.m. Motor-driven barring gear is provided for each engine, the motors being fitted with a "knock out" switch, which automatically trips out the motor when the engine reaches a predetermined speed, thereby ensuring that the engines cannot "over run" the barring gear.

Between the months of March and July, 1915, the whole of the engines were submitted to a searching and elaborate system of duty trials, conducted under the supervision of Mr. T. H. Smith, Assoc.M.Inst.C.E., and Mr. E. H. Wingfield, representing the Main Drainage Department and the Mechanical Service Department of the Egyptian Government respectively. A series of eight trials in all was carried out on the main engines, three being of 24-hours' duration, and five of 12-hours' duration each. At each individual trial the conditions were adjusted to subject the engines to a fixed set of conditions with regard to speed, steam pressure, superheat and head, so as to obtain a complete record of performance under all conditions called for in the official specification.

The guarantee entered into by the contractors was a consumption not exceeding 12·0 lb. of steam per hour per horse-power actually developed by the main pumps, measured by the actual weight of water lifted, and inclusive of all power absorbed by the auxiliary pumps attached to the main engine, and also of the heat absorbed in the jacket system. The conditions of the guarantee provided that steam should be furnished at 200 lb. gauge pressure and superheated by 180 degs. F., and that the engines should be working at their full normal speed and power.

The best result actually obtained was a consumption of 10·28 lb. per p.h.p. per hour, with a mean steam pressure of 197·6 lb. gauge, at a total temperature of 545 degs. F., corresponding to practically 160 degs. F. superheat. The figures given in the annexed tabular statement are abstracted from the official log sheets of the normal power trial on No. 1 engine, and will be of interest.

The conditions under which this trial was run are those of ordinary daily service, and consequently the figures closely represent those normally maintained by the engines as ascertained from carefully kept daily log sheets of coal consumption for the whole period five months over which the official trials extended.

Table giving Results of Normal Power Trial of Engine No. 1.

Date of trial	19–4–15
No. of engine	1
Duration of trial—hours	12
Barometer—inches	29·850
Net displacement of plungers per rev. galls.	137·907
Mean r.p.m.	23·420
Mean galls. per minute	3,229·800
Mean total head ft.	144·000
Mean pump horse-power	140·940
Mean ind. horse-power	155·080
Mechanical efficiency	90·880
Mean steam pressure, lbs.	198·010
Mean steam temperature deg. F. ...	522·000
Mean superheat degs. F.	138·000
Mean vac. corrected for barometer ins.	25·910
Steam per p.h.p. per hour, through cylinders ... ... lbs.	9·990
Water drained from jackets per hour... ... ... lbs.	272·800
Water drained from oil separator, per hour ... ... lbs.	9·400
Gross b.t.us. supplied to jackets and reheaters per hour... ...	349,729
Total b.t.us. returned to boilers through feed heater per hour ...	217,305
Net total steam used by engine per hour ... ... lbs.	1,512·080
Steam per i.h.p., per hour ... lbs.	9·750
Steam per p.h.p., per hour ... lbs.	10·720

THE 300-H.P. MAYBACH AERO-ENGINE.

(*Continued from Page* 228.)

Valves and Valve Gear.—The twin inlet and exhaust valves work vertically in cast-iron valve stem guides in the cylinder heads, and are operated by rocker levers mounted on roller bearings, each pair of valves being operated by a single tappet rod from one of the camshafts in the crank-case. The heads of all the valves, both inlet and exhaust, are of the same diameter, *i.e.*, 54 mm., and the angle of the valve seatings is 30 deg. in each case. The inlet valves are machined concave under the head, and are formed with a 20-mm. radius between the valve steam and the head. The exhaust valves are convex in the head, and are made with a compound radius between the valve stem and the head of 9 mm. and 25 mm. The diameter of all the valve stems is 11 mm., the clearance in the guide bushes being 0·12 mm. (inlet) and 0·15 mm. (exhaust) (cold). The ends of the valve stems are fitted with hardened steel discs, which are bedded in the recessed ends of the stems.

The inlet valves are 136·5 mm. long overall, whilst the exhaust valves are 152·5 mm. in length. The exhaust valves are made longer to allow for the extra water cooling space in the cylinder head above the exhaust valve pocket already referred to.

All the valve springs, however, are of exactly the same length, *i.e.*, 52·5 mm. free, and measure 39·5 mm. when in their position in the cylinder, initially compressed with no valve lift. The diameter of all the valve springs is the same, 51 mm. (central diameter of coils), and the gauge of wire is 5·22 mm. in all cases. The valve springs are fitted with plain collars at the top. These are secured by T-shaped cottars through the valve stems in the usual way. These are also locked in position with small wire clips, which are fitted to the spring cotters through two small holes. The surface of all the valve spring collars is galvanised or plated with a tin or zinc deposit of some nature, apparently to prevent corrosion. This form of galvanised exterior finish is carried out on several other parts of the engine. Details of the valves and valve springs are given in Figs. 18 and 19, on page 253.

Valve Rockers.—The roller bearings carrying the spindles of the valve rockers are mounted in short brackets, each of which is attached to the cylinder heads by two 8-mm. studs and castellated nuts. The bearing brackets are steel drop-forgings, and the roller races are, to a certain extent, permanently fixed inside the recessed heads of the brackets, and are covered by thin steel discs fitted over the front faces of the bearings, these being held in position by a form of mechanical knurling largely used in German aero-engine manufacture. This mechanical process takes the form of spinning or riveting over the housing metal of the part by a series of accurately spaced indentations.

The hardened steel set screws for the adjustment of the tappet clearances are drilled with a 5-mm. hole in the centre portion through the squared end only, and the usual form of transverse locking bolt is provided. The method of splitting the lever to provide for the locking of the tappet adjusting screw, however, is carried out in a somewhat unusual way. This is shown in the view of the rocker lever in Fig. 19, from which it can be seen that the saw-cut is made from the tappet hole, which takes the tappet adjusting screw backwards through the centre of the rocker lever towards the rocker spindle A steel stud having a hardened hemispherical end, which makes the top joint of the valve push rod, is fitted on the outer lever of the valve rocker. These steel studs are driven tightly into the levers, and are secured by small steel wire rings snapped over semi-circular grooves cut in the top ends of the spherically-ended studs.

The tappet push rods are made of steel tube, 16 mm. outside diameter, and are fitted with hemispherical hardened steel cups at each end; these are fixed to the push rods by taper pins and weigh 0·48 lb. each. Hardly any alteration has been made in the familiar tappet design. The tappets consist of hollow, steel tappet barrels, which are plugged at the top ends by hardened steel caps; the tops of these caps are formed with hemispherical heads, which engage with the lower ends of the cupped push rods. The hardened cam rollers are held in position by the grooves machined in the bottom ends of the tappet barrels; these grooves are made slightly more than a semicircle to prevent the roller from falling out. Side movements of the rollers is prevented by the tappet guides. The cam rollers are 15 mm. in diameter, and are bored with a 4·5 mm. hole. Four small holes are bored radially in the sides of the hollow tappet barrels, which always carry a certain amount of oil, thus providing a very simple, efficient method of lubricating the tappet guides. These are made of gun-metal, and the general design is clearly shown in the cross-sectional drawings and also in Fig. 19.

A vertical lug is provided on the top of each tappet guide, which forms the guide for the tappet barrel, and prevents it from rotating. Three oil grooves are machined inside the tappet guides.

Valve Gear of 300-h.p. Maybach Aero Engine. Weights of Reciprocating Masses.

	Oz.		Oz.
Weight of two valves ...	15	Weight of tappet rod	3
Half weight of two springs ...	4½	Weight of plunger	6½
Weight of two spring caps ...	3	Weight of roller	1
Equivalent weight of rocker ...	4		15½
	26½		30
			45½

Multiply by ratio of 35 : 31 = 30 ozs.
Total reciprocating mass at cam, 2 lb. 13½ oz.

Spring.

Effective coils	3
	mm.
Thickness of wire (diameter)	5·5
Mean diameter	51·0
Free length	52·0
Minimum length	29·0

133 lb. pressure axially when valve full open.
32 tons stress.

Cams and Camshafts.—Both the inlet and exhaust cams are of the same profile, although the valve lift is slightly greater for the exhaust valves, according to the valve-lift diagram reproduced in Fig. 20, which has been calculated from the actual valve setting of the engine under test. This difference is due to the unequal tappet clearances. Details of the cam design are given in Fig. 21. The cams are made in pairs, machined from solid forgings. Each pair of inlet or exhaust cams is fitted to the camshaft separately. Each camshaft is provided with three key-ways, which are machined along the whole length of the shaft. The cam blocks are made with three keys cut inside the hole which is bored in the cam blocks, the keys being solid with the cams. The cam blocks are also fixed to the cam-shaft by taper pins to prevent lateral movement. The central portion of each cam block between each pair of cams is machined to a diameter of 49 mm. by 16 mm. in width. These portions of the cam blocks form the journals of the camshaft bearings. They run in plain phosphor-bronze bushes let into the top half of the crank chamber, and helical oil grooves are cut in the face of the bearing journals on the camshaft. Each cam block is also fixed in position in the camshaft by one 5 mm. set screw which prevents the cams from moving laterally in the keyways.

The five bronze bushes forming the camshaft bearings are pressed into the crankshaft bearing webs of the crank chamber; the front and rear camshaft bearings are fitted with a flange, and are detachable; they are twice the width of the other three on account of the camshaft driving gears which are fitted on the front end of the camshafts, and the magneto driving gears, &c., which are fitted to the rear ends of the camshafts.

The setting of the valves is shown in the diagram, Fig. 21, page 253, which shows the following valve positions, viz. :—

Inlet valve opens	8 deg. E.
Inlet valve closes	35 deg. L.
Exhaust valve opens	33 deg. E.
Exhaust valve closes	7 deg. L.
Period of induction	223 deg.
Period of exhaust	220 deg.

Further details of the valve gear and cam design are given in the list of data at the end of this report, and in the diagrams, Figs. 22 and 23, on page 254.

Crankshaft.—Details of the design of the crankshaft are given in the dimensioned drawing, Fig. 17, on page 230 *ante.** The crankshaft runs in seven plain bearings lined with anti-friction metal of the usual formation. All the journals are 66 mm. in diameter The diameter of the crank-pins is also 66 mm. The crank-webs are all of the same section, being 23 mm. in thickness and 95 mm. in width across the face. All the journals are bored 36 mm. diameter. The crank-pins are bored 30 mm. diameter, the ends of the holes being plugged with the centrifugal oil scoops characteristic to the Maybach engines. (Details of these are dealt with later in the notes on lubrication.) The rear end

* A perspective view of the crankshaft was also given in Fig. 5 of Plate XIX, published in our last issue.

of the crankshaft carries the extension shaft, on which is mounted the wireless dynamo driving pulley, which embodies a friction clutch. This design of wireless pulley is a standard German engine fitting.

The extension shaft referred to above is a driving fit in the rear end of the crankshaft, which is bored 42 mm. the extension shaft is locked by a 7-mm. taper pin. Two centrifugal oil-thrower rings are machined on the extension shaft. These details are shown in the general arrangement of the engine in Fig. 14, on page 230 *ante*.

the front end of the flange, the hole being drilled half in the flange and half in the crankshaft. The grub screw is locked by the flanged head of a large plug 40 mm. diameter, which is screwed into the hollow front end of the crankshaft. This flange, to which the propeller hub is secured by eight 14-mm. bolts with countersunk heads, is mounted on a large single race ball-bearing 132 mm. outside diameter, behind which is fitted the double thrust ball race, 108 mm. diameter on the ball centre diameter.

the propeller hub and flanges is galvanised with deposited tin to prevent corrosion. The front flange floats on the propeller hub in four castellations, 17 mm. wide by 3 mm. deep. The total weight of the complete propeller hub, with all bolts, less extension flange on end of crankshaft, = 21 lb.

Crank Chamber.—The photographs, Figs. 6 and 7, given on Plate XIX, published last week, show clearly in perspective the general formation of the cast aluminium base chamber. Unlike most of the enemy

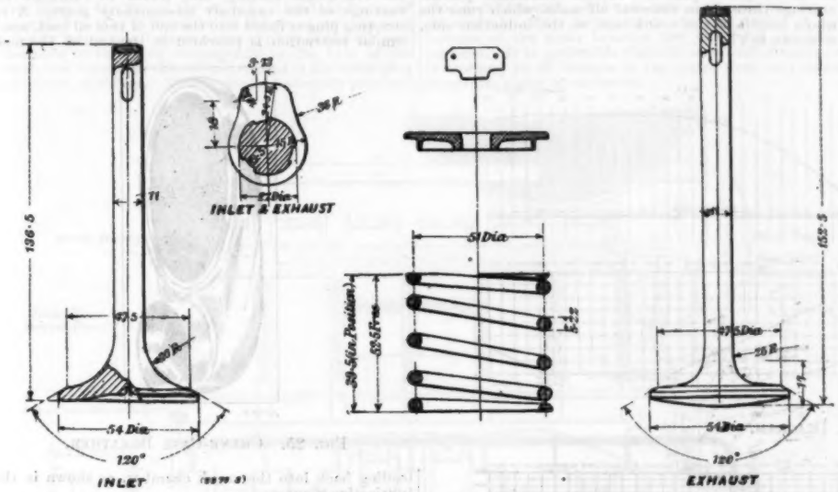


FIG. 18. DETAILS OF VALVES, CAMS AND SPRINGS.

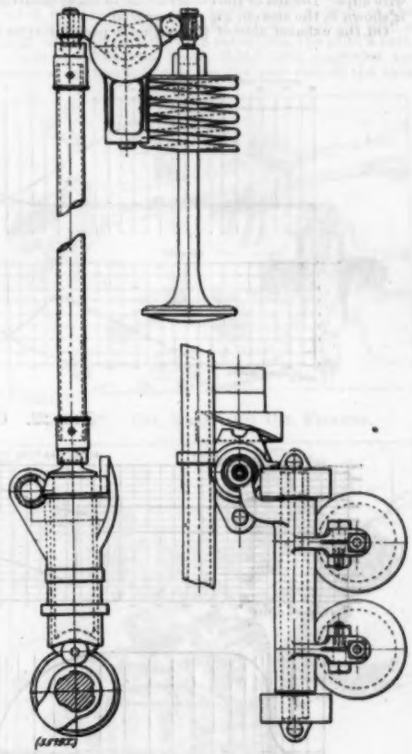


FIG. 19. VALVE GEAR.

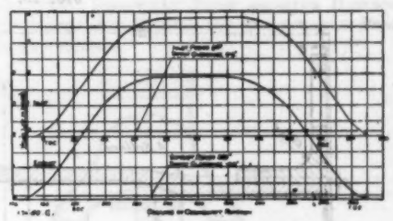


FIG. 20. DIAGRAM OF VALVE LIFT.

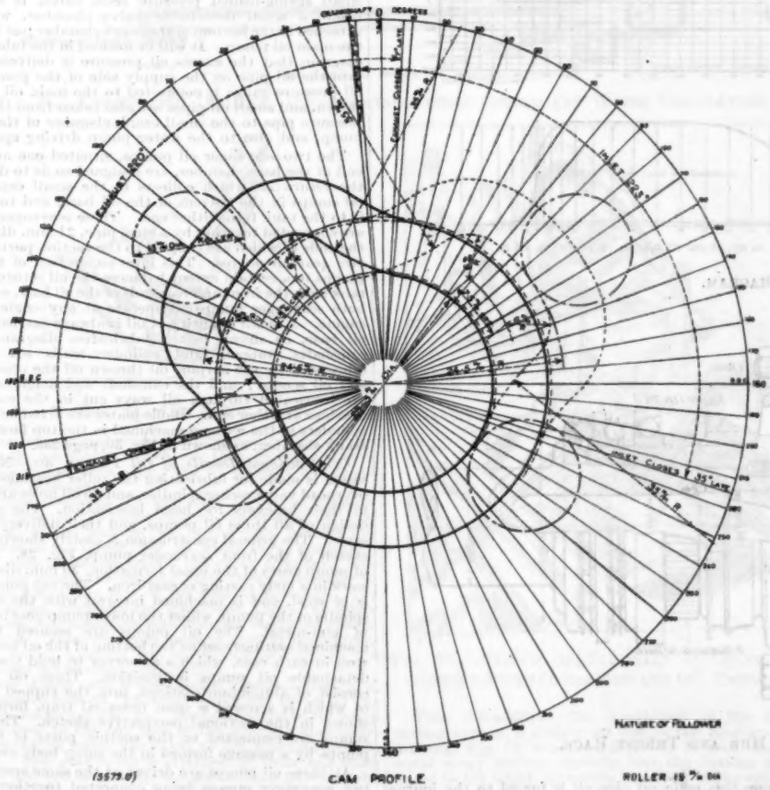


FIG. 21. CAM DIAGRAM AND VALVE TIMING.

The main driving bevel gear is fixed to the rear end of the crankshaft by a key 8 mm. wide by 5·5 mm. deep half sunk in the shaft.

An interesting point in the design of the crankshaft is found in the method of fixing the flange to which the propeller hub is bolted. The construction is clearly shown in the sectional arrangement of the propeller hub in Fig. 24, page 254, from which it will be seen that a slight taper, 1 in 33·3 mm., is machined on the front end of the crankshaft, on to which the propeller hub flange is very tightly driven. No key is fitted to the taper, but a grub screw 10 mm. diameter is screwed into

On the front portion of this propeller hub carrying flange is mounted a double oil-thrower ring, which is driven on to the outer diameter of a split collar or bush as shown in Fig. 24. The driving gear for the camshafts is machined on this propeller hub flange; the teeth of the gear are integral with the flange, hence the splitting of the bush which carries the double oil-thrower rings.

Propeller Hub.—The general details of the construction of the propeller hub are given in Fig. 24. Eight 15-mm. bolts are used to bolt the front flange to the two rear propeller hub flanges, and the propeller is secured by castellated nuts in the usual manner. The surface of

aero engines, the bottom halves of the crankshaft main bearings are bolted to the top half of the crank chamber. These are very deep in section, and are secured to the crank chamber by 19 mm. diameter bolts, which pass through the crank chamber, and are also used to bolt down the cylinders by means of triangular clamps, now almost standard practice. Flanges are machined on the top ends of the holding-down bolts, and these are let into recesses cut in the top face of the crank-case. The front main bearing cap also carries below the intermediate gear pinion for driving the oil pumps as shown in the general arrangement of the engine. Cast aluminium covers are bolted to the front and rear ends of the crank-case for enclosing the camshaft driving gears at the front end, and for the magneto and interrupter gears at the rear end of the engine.

Base Chamber.—The general construction of the lower half of the crank chamber is shown in Fig. 8, on Plate XIX *ante*, and also in the sectional general arrangement drawing. It presents several points of interesting design, and is of simple construction, weighing 41·32 lb. bare. At the rear end of the flange, which is bolted to the top half of the crank chamber in the usual way, extended brackets are cast for taking the two magnetos, and, as will be seen in Fig. 8, the three-gear type oil pumps are situated on seatings cast on the bottom of the inside of the base chamber. The small detachable oil sumps are fixed to flanges cast on the underside of the base, one at each end. Details of the construction

of the oil pumps and detachable oil sumps are given in the notes on lubrication.

Crank-case Ventilation.—As in the Zeppelin-Maybach engines, the efficient ventilation of the crank-case has received careful consideration. The design is, in fact, very similar in both types of engine. On the eduction side of the engine six breathers are fitted; these are constructed of fairly coarse brass wire-gauge baffles mounted in sheet aluminium breathers which are attached to short steel tubular connecting lugs screwed into the crank-case, and are fixed in position by steel wire clips. Details of the construction of these breathers is shown in the sketch, Fig. 25, annexed.

On the exhaust side of the engine a peculiar type of ventilator is fitted. This consists of a sheet aluminium manifold, which is connected by six short rubber joints to the crank chamber. The top portion of the ventilator manifold is so made as to form an oil trap for the condensed vapour. This consists of an elliptical section pipe, which leads from the top of the chamber formed in the ventilator manifold to a cowl which projects backward from the outside of the engine cowling in the machine. This crank-case ventilator is shown in the photograph of the engine, Fig. 2, on Plate XIX *ante*.

Lubrication.—Several details of the lubrication system have been completely redesigned in the new Maybach engines. The former single oil pump, which was of the plunger type, has now been replaced by three separate oil pumps of the gear type. These, as shown in Fig. 8, Plate XIX *ante*, are fitted in the bottom of the base chamber. The main oil-pressure pump is at the rear end, whilst the two scavenger pumps are situated one at each end of the base chamber.

The general principle of the lubrication system is here clearly shown in the special diagrammatic drawing Fig. 26, which is to a great extent self-explanatory. In this diagram the lubrication system is shown with all the oil pipes and oil-ways marked in black. The system briefly described is as follows: Oil is delivered from the separate oil tank by the pressure oil pump, which is the rearmost pump of the two at the rear of the sump, and forces oil under pressure to the crankshaft journal bearings through an external oil main, which runs the whole length of the crank-case on the induction side, as shown in Fig. 27.

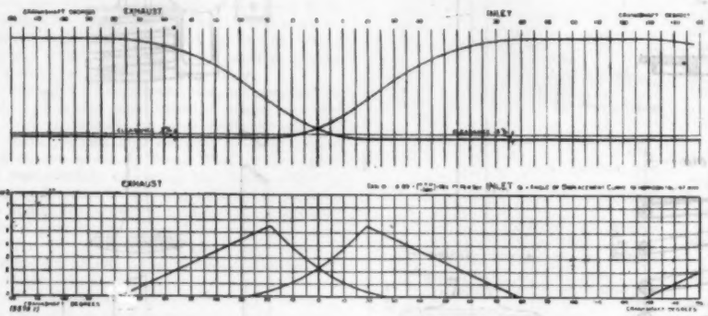


FIG. 22. CAM DIAGRAM.

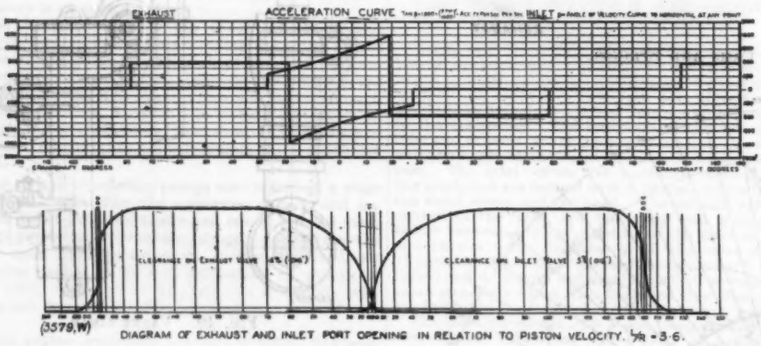


FIG. 23. CAM DIAGRAM.

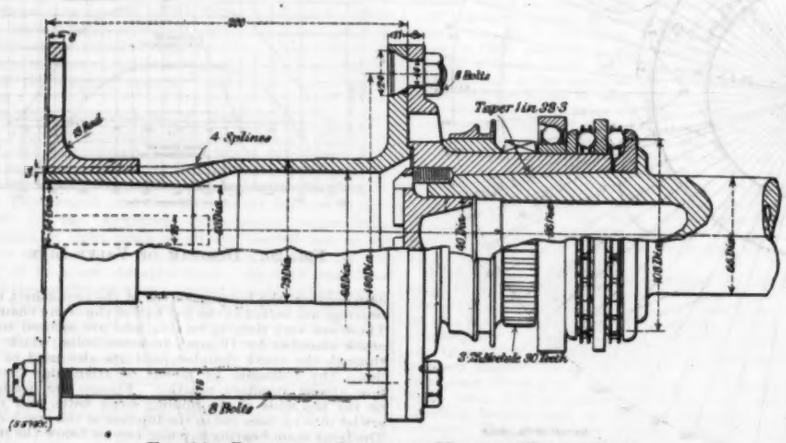


FIG. 24. DETAILS OF PROPELLER HUB AND THRUST RACE.

From this main oil pipe oil is forced to the journal bearings through oil ways drilled diagonally in the crank chamber casting through the transverse webs which support the housings of the journal bearings; these are lubricated by a wide helical oil groove cut in the bearing white metal. For the lubrication of the crank pins and the connecting rod small-end bearings, the well-known Maybach system of centrifugal pressure lubrication is adhered to. In this system the oil, which is forced out through the ends of the journal bearings, is collected by the oil scoops, which are bolted to the outer sides of each crank-webs, as shown in the view of the crankshaft already referred to.

By centrifugal action the oil is forced up the outer surface of each crank-web and led through a channel into the hollow crank pins, thence through a small hole bored radially in each crank-pin to the connecting rod big-end bearings. From the big-end bearings the oil is forced upwards to the small-end bearings, with their floating gudgeon pin bushes of cast-iron, through the steel pipe fixed in the centre of the connecting rods. Details of this design have already been given. Fig. 29 is a detail sketch of one of the aluminium oil scoops, which are bolted in pairs to the crank webs by a bolt which passes through the centre of the end crank-pin. From the front end of the main oil pipe a steel pipe is connected by a union, which leads to a hole drilled in the crank-case casting, and serves to lubricate the bearings of the camshaft intermediate gears. A restricting plug is fitted into the end of this oil lead, and a similar restriction is provided in the end of the main

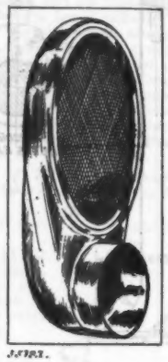


FIG. 25. CRANK-CASE BREATHER.

leading back into the crank chamber, as shown in the lubrication diagram.

A check valve, it will be noticed, is fitted in the main oil supply system. This check valve, together with a small spring-loaded pressure relief valve, is situated inside a small detachable valve chamber, which is attached to the bottom of the crank chamber just beneath the main oil pump. It will be noticed in the lubrication diagram that the excess oil pressure is delivered back into the oil pipe on the supply side of the pump. An oil pressure gauge is connected to the main oil lead as shown, and small oil pipes are also taken from the main pressure pipe to the small crank chamber of the petrol pump, and also to the water pump driving spindle.

The two scavenger oil pumps, situated one at either end of the base chamber, are designed so as to draw off the return oil which collects in the small detachable oil sumps in the bottom of the oil base, and to return it to the tank from either end. These scavenger pumps are connected together by a steel pipe, 21 mm. diameter, the ends of which are coupled to the suction ports of the two gear oil pumps. This inter-connection of the two pumps to a certain extent balances the oil return to the tank from the front and rear ends of the oil base, enabling both scavenger pumps to operate at any angle of the engine. A small quantity of oil is always carried in the oil base, as shown in the lubrication diagram. The camshafts, tappets and cylinder walls are splash lubricated by the surplus oil thrown off the crankshaft and oil scoops; and the camshaft and magneto gears are lubricated through oil ways cut in the camshaft bearings at either end. Baffle plates are fitted below the cylinders in the recesses machined in the top face of the crank chamber, as shown in Fig. 30, page 255.

Constructional Details of Oil Pumps, &c.—No provision is made for lubricating the roller bearings of the overhead valve rocker spindles, and no oil holes are made in their brackets for hand lubrication. The general design of all three oil pumps, and their delivery is the same. The general construction is clearly shown in the sketch of the front scavenger pump, Fig. 28. A pair of pump gears of the usual formation, 30 mm. diameter, work in a body casting of cast-iron. The top pump gear is of steel, and is machined integral with the driving spindle of the pump, whilst the lower pump gear is made of gun-metal. The oil pumps are secured to the machined seatings cast on the bottom of the oil base by a stud in each case, which also serves to hold the small detachable oil sumps in position. These oil sumps consist of aluminium castings, into the cupped centre of which is screwed a spun brass oil trap, formed as shown in the sectional perspective sketch. These oil sumps are connected to the suction ports of the oil pumps by a passage formed in the sump body castings.

All three oil pumps are driven at the same speed, the two scavenger pumps being connected together by a light tubular shaft which engages with dog clutches at either end; the pressure oil pump is driven off the spindle of the rear scavenger pump through a dog clutch extension of the spindle. The method of driving the oil pumps at the front end of the engine is of interesting and unusual design. As shown in the sketch, Fig. 28, the driving gear wheel, which is mounted on the front extension of the pump spindle, is provided with a spring-loaded face ratchet, the teeth of which are cut inside the gear as shown, and engage with similar teeth cut on a flange on the front of the pump driving spindle. The strength of the spring is such as to allow the driving gear to overrun the driving spindle, and apparently in the event of backfiring, all the oil pumps become inoperative, and oil would thus be prevented from being sucked back into the oil base by the two scavenger pumps.

An interesting feature in the lubrication system of these engines is found in the small separate oil filters which are provided at the top of each of the diagonal oil ways drilled through the webs of the main journal-bearing housings. The small filters are screwed into the bosses, which are cast on the outside of the crank chamber, and to which the detachable main oil pressure pipe is attached.

In Fig. 27 the method of attaching the main oil pipe by a set screw and a cap fitted with a leather washer is shown. The set screw is screwed into the top of the filter plug at the top of the drilled oil lead, and a small jet or drilled plug is fitted below the set screw, the plug being let into a small recess cut in the top of the oil lead. The bore of this plug corresponds to the bore of the restriction formed in the oil lead drilled in the filter plug just below, as shown. This device is apparently provided which the diagonal water pipe from the radiator is coupled by a rubber connection. The top half of the water pump body, which is a gun-metal casting, is formed with six helical passages leading in a reverse helical direction to the water pump rotor. These passages connect with the common vertical outlet passage in the top of the body casting, as shown in Fig. 31. The outlet diameter is 50 mm.

The centre portion of the top body casting inside the helical passages above the pump rotor is domed and fitted with a screwed plug, 38 mm. in diameter. This plug is drilled with a 3·5 mm. hole, evidently to prevent an air-lock. Two 3-mm. holes are also drilled in the bottom of the rotor between the vanes for the same purpose. It is noticeable that the steel ball thrust race is working to all intents in the water flow, and must, therefore, suffer by corrosion.

tubes, and exceptionally deep in cross-section, measuring 22 cm. The radius of the semi-circle in elevation is approximately 32 cm. The radiator is divided into two separate sections by a vertical baffle plate, as shown in the diagram, Fig. 26. Water enters the bottom of the left-hand side of the radiator through the pipe leading from the front carburettor, and flows upwards through the tubes of the left hand of the radiator to the top portion of the tank which completely surrounds the radiator. The water passes over the top of the dividing baffle plate, through the right-hand section to the bottom of the radiator, and out at the rear side, which is connected with a 50 mm. pipe to the inlet passage of the water pump. The front of the radiator is fitted with a blind, which is operated by a cable from the pilot's seat.

Ignition.—The two Bosch Z.H.6-type magnetos are mounted on brackets cast on the rear end of the base

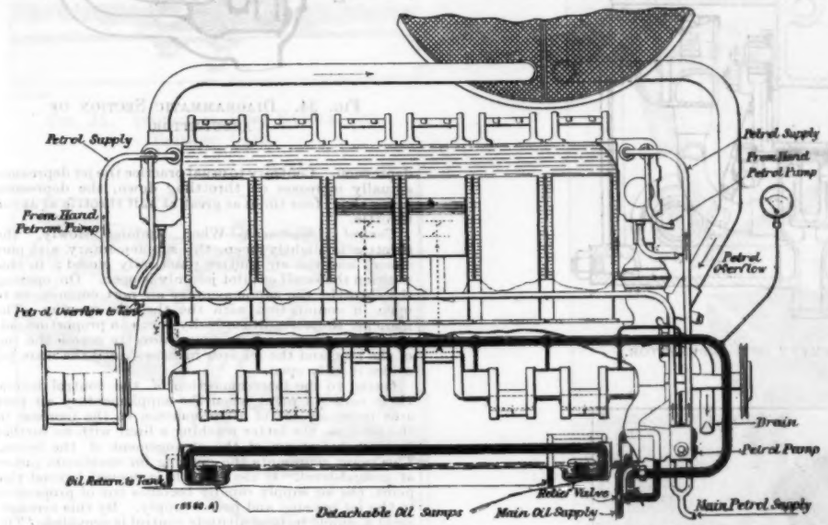


FIG. 26. LUBRICATION DIAGRAM, ALSO SHOWING PETROL SYSTEM AND WATER CIRCULATION.

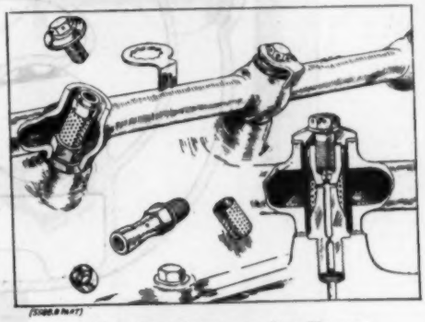


FIG. 27. OIL MAIN AND OIL FILTERS.

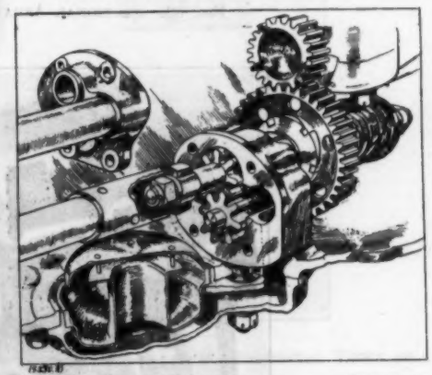


FIG. 28. FRONT OIL PUMP SHOWING RATCHET DRIVE AND SECTION OF DETACHABLE PUMP IN CHAMBER.

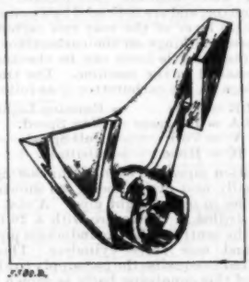


FIG. 29. OIL SCOOP.

FIG. 30. SKETCH OF TOP HALF OF CRANK-CASE SHOWING JOURNAL BEARING AND OIL PASSAGES.

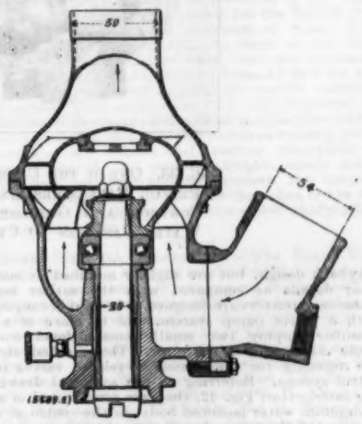


FIG. 31. SECTION OF WATER PUMP.

to allow for a special plug to be attached in place of any of the six set screws, which can then be coupled to a pressure gauge, thus giving the oil pressure at any of the main bearings.

Further details of the formation of the oil passages drilled through the crank-case to the journal bearings and also of the construction of the main bearing cap are given in the sketch, Fig. 30, which shows the underneath view of the top half of the crank chamber. The oil is led round the bearing bolts through circular oil grooves cut in the face of the bearing housings. The small holes, drilled in the crank-case above the joints as shown, communicate with recesses machined around the bolts. These holes are made to prevent the oil from being forced upwards out of the engine through the bolt holes in the crank chamber.

Water Pump and Water-Cooling System.—Details of the construction of the water pump are shown in the sectional drawing, Fig. 31. The body of the water pump is attached to the top face of the separate aluminium casting which forms the cover of the magneto driving gears. This gear cover is attached by bolts and studs to the rear end of both the top and bottom halves of the crank chamber. As may be seen in the general arrangement drawing of the engine, the water pump spindle is driven through a dog clutch at its lower end by a short vertical spindle running in a bronze bush bearing; this spindle is driven by a bevel gear meshing with the main bevel fixed on the rear end of the crankshaft. The water pump vertical spindle, which is 20 mm. in diameter, runs in a bronze bearing, which is lubricated by a screw grease-lubricator. The top portion of the pump spindle bearing is cupped to form the housing for a thrust ball race, above which is fixed the pump rotor. The pump rotor is a gun-metal casting, having six helical vanes, 110 mm. in diameter. The rotor is fixed to the pump spindle on a taper and key, and is locked by a domed nut and locking washer.

The lower half of the pump body is an aluminium casting with an inlet passage 54 mm. in diameter, to

Water Circulation.—The circulation of the water-cooling system is clearly set out in the diagrammatic drawing, Fig. 26, from which it will be seen that the water pump delivers directly into the bottom of the water jacket which surrounds the body of the rear carburettor. As already mentioned, the two carburettors are attached by long studs to the ends of the front and rear cylinders, and the water, after passing through the rear carburettor water jacket in a special passage round the throttle valve, enters the rear cylinder through the two circular water-joint flanges. The water passes through the passages cast in each of the six cylinder heads to the front carburettor water jacket, whence the water is forced out through a vertical passage 50 mm. diameter through a diagonal pipe leading to the radiator, which is slung above the engine from the centre section of the top plane.

The radiator is of entirely new design, and is shown in Fig. 33, on the next page, fitted to a 260-h.p. Mercedes engine. According to a French report, this radiator is very efficient. It is of semi-circular shape in front elevation, and is formed of hexagonal honeycombed

chamber, and are driven at 1·5 : 1 engine speed directly off the rear end of the camshafts. The ignition point is set 38 deg. early. Two Bosch 3-point plugs are somewhat inaccessibly fitted in the head of each cylinder between the twin water connections as previously described. The plug bosses are water cooled. The high-tension cables are carried in fibre tubes bolted to the cylinders, and the leads to the plugs are taken through fibre blocks mounted on the sheet-metal brackets on the cylinder heads. The order of firing is: 1-5-3-6-2-4.

Carburettors.—The two carburettors are attached to the heads of the front and rear cylinders, as already described, and their general construction is shown in the cross-sectional drawing, Fig. 32. The carburettors follow the distinctive principles of the well-known

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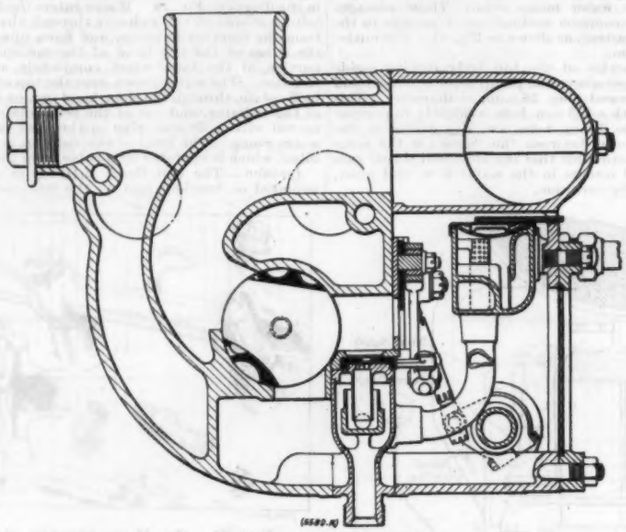

Fig. 32. Sectional Arrangement of Carburettor.

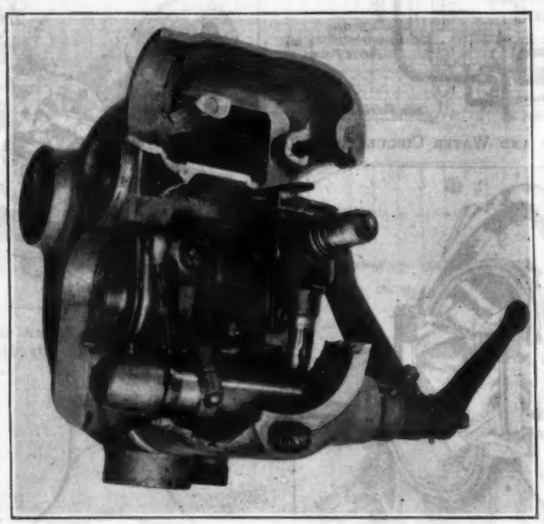

Fig. 33. One of the Carburettors Broken to show Gravity Petrol Reservoirs and Inter-Connected Throttle, Jet Control and Guillotine Shutter, also Induction and Water Passages to Cylinders.

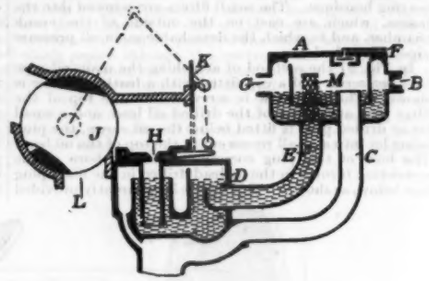

Fig. 34. Diagrammatic Section of Carburettor.

Maybach design, but are slightly modified in many of their details as compared with the earlier engines. These carburettors are designed to be used in conjunction with a petrol pump system, and in place of a float chamber employ two small constant-level overflow tanks inside each carburettor. This method obviates the necessity for using pressure-release valves in the petrol system. Referring to the sectional drawing of the carburettor, Fig. 32, they are constructed of a cast aluminium water jacketed body, in the centre of which is mounted the rotary barrel-type throttle, open on one side to the curved passage to the induction pipe, and on the other to the mixing chamber above the jets. The main air supply is taken through a passage cast in the aluminium carburettor body directly below the throttle and the extra air supply is automatically controlled by a guillotine-type shutter, which works vertically just in front of the jet control lever. The throttles of both carburettors, together with the mechanically-controlled jets and the extra air shutters, are all interconnected. The arrangement of these cranks and interconnecting levers is shown in the view of the specially-sectioned carburettor, Fig. 33.

The working principle of the carburettors and the functions of the various parts is more clearly demonstrated in the purely diagrammatic sectional drawing Fig. 34, which is, to a great extent, self-explanatory. Petrol is delivered by the petrol pump into the small tank A of each carburettor through a restricting jet B, shown in the diagram. The petrol in these small tanks or reservoirs is kept at a constant level by means of the overflow pipe C, which leads back to the main petrol tank, *via* the small lower tanks D below the jets which are supplied through the pipe E. An air vent F, fitted with a baffle plate, is provided in the top of the constant-level tank A, which is also connected to the main petrol tank by a pipe G, leading to a hand petrol pump, or may be plugged and not used, as was the case in the Rumpler biplane. The main and pilot jets consist of two holes drilled in the top cover of the lower reservoir D, and are similar in principle to the White and Poppe jets. The area of the jet openings is mechanically controlled by means of a small hole drilled eccentrically in the jet cap H, which, as previously described, is connected by levers to the throttle and air-control levers. The function of the top tank A is apparently to deal with the large excess of petrol delivered by the petrol pump at high speeds, whilst the lower tank, which is gravity fed, provides a constant petrol level for the jets.

The mixture strength at any point on the throttle curve is governed by purely mechanical means, there being no venturi or special jet arrangement. The jet depression is obtained by restricting the air flow at what approximates to a sharp-edged orifice; consequently the loss through the carburettor is very high compared with a carburettor using a venturi tube to get the jet depression. Contrary to usual practice the jet depression actually increases on throttling down, the depression being about four times as great at half-throttle as at full throttle.

Control Adjustment.—When running slowly, the throttle is slightly open, the supplementary air port closed, and the air shutter practically closed; in this position the small or pilot jet only is open. On opening the throttle, the supplementary air port commences to open in conjunction with the throttle opening. The main air shutter automatically opens in proportion, admitting more air, which passes directly across the top of the jets, and the jet area increases until the main jet orifice is fully open.

Owing to the interconnection of the control levers, there comes a point when the supplementary air port area increases out of all proportion to the increase in the jet area, the latter reaching a limit with no further increase by reason of the arrangement of the levers. This point represents the opening for maximum power at ground-level. If the throttle is opened beyond this point, the air supply rapidly becomes out of proportion to the jet opening and petrol supply. By this arrangement a simple form of altitude control is provided. The various positions for "slow running," "slow speed," "full speed," and "altitude" are marked on the body of the carburettor, and are indicated by a pointer attached to the throttle lever of the rear end carburettor. By means of these markings on the carburettor the correct settings of the throttle lever can be checked when the engine is installed in the machine. The translation of these markings on the carburettor is as follows:—

LE = Leer	=	Running Light.
LA = Langsam	=	Slow Speed.
V = Voll	=	Full Speed.
H = Hohe	=	Altitude.

The induction pipes are aluminium castings, and are of exceptionally neat design, being, as shown in Fig. 35, joined together in one straight pipe. A cast aluminium baffle plate drilled in the centre with a 20-mm. hole is provided in the centre of the two induction pipes between the front and rear three cylinders. This baffle is evidently fitted to equalise the gas supply to all cylinders. The design of this equalising baffle is shown in the perspective sketch, Fig. 35, which also shows the method of joining the ends of the induction pipes by rubber connections and band clips. Details of the six small primer valves fitted into the top of the induction pipe are also shown in the sketch. Fig. 36 clearly shows the construction of the interesting type of band clip which is used for making the connections in the induction pipes and also for most of the water joints on these engines. These clips are now extensively used on all enemy engines. The clips are made of thin strips of annealed spring steel; these are wound twice round the rubber rings and fastened by small steel links and bolts. In starting to make this joint, the end of the steel band is first bent over the bottom bar of the connecting link, and then wound twice round the rubber ring, the free end of the steel band passing through the centre portion of the connecting link on the second winding. The end of the steel band is then fastened to the top end of the link by coiling the end several times round the small bolt in the head of the link, the end of the steel band being bent over for about 2 mm., and inserted into a slot cut in the bolt, so that by turning the bolt in the link the steel band is wound tightly round the ring joints, and, owing to the position and shape of the link, remains fixed.

Carburettor Tests.—The Maybach carburettor has been tested separately at R.A.E. The results of these tests is shown graphically in the power and throttle curves (Fig. 38), together with a throttle curve diagram in comparison with the H.C. 8 Claudel-Hobson carburettor (Fig. 39).

Characteristic Curves.—(*a*) Throttle Curve.—The throttle curve appears good. There is an excess of petrol at first which should give good acceleration, and there is a fair range, down from full throttle, of weak mixture suitable for cruising. Obviously, if it is considered desirable to have petrol and air control interconnected, any required throttle curve could be obtained, but it makes an unnecessarily complicated instrument. In this particular carburettor there are four ball universal joints and two sliding blocks.

(*b*) Power Curves.—The power curves are satisfactory,

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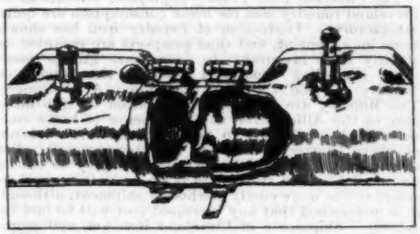


FIG. 35. INDUCTION PIPE BAFFLE AND PRIMING CAPS.

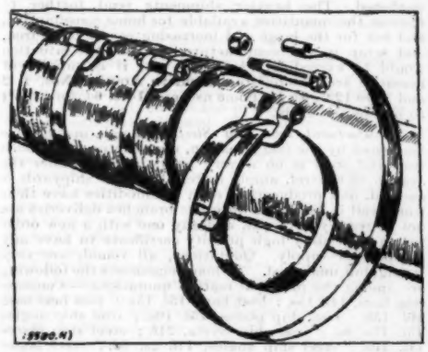


FIG. 36. STEEL BAND JOINT CLIP USED ON RUBBER CONNECTIONS OF INDUCTION PIPE AND WATER JOINTS.

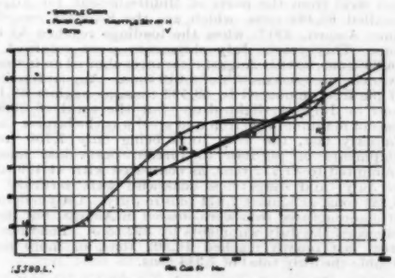


FIG. 38. CARBURETTOR TEST; THROTTLE CURVE DIAGRAM.

the mixture being practically constant over a large air speed range.

Resistance Test.—The resistance is very high compared with carburettors of ordinary design. For purposes of comparison, the resistance of the H.C.8 Claudel-Hobson carburettor is plotted on the same curve. The two carburettors are for engines of about the same horse-power, and it will be seen that the resistance of the Maybach is about nine times that of the Claudel-Hobson.

Atomisation Test.—Results as follow:

—	Air Temperature. Deg. F.	Air, Cub. Feet per Minute.	Petrol, Pints per Hour.	Deposit c.c. per min.	Deposit per cent. of Petrol Flow.
Maybach ..	58	192	50	23	4·85
H.C.8 Claudel-Hobson ..	58	195	51	32	6·62

The atomisation of the Maybach is rather better than the Claudel-Hobson, but this is obtained by a high depression and high loss through the carburettor.

Conclusion.—The carburettor seems satisfactory on throttle and power curves and atomisation, but the resistance is very high and the weight excessive. The throttle curve is obtained by a complicated mechanical system which would need careful first adjustment and constant adjustment for wear. The air is taken in through the moving parts, and if any dust is present the mechanism is very liable to stick or to render the control very hard to operate.

Petrol Supply System.—Petrol is supplied to the two carburettors by a small double-acting duplex petrol pump, which is attached to the rear end of the bottom half of the oil base, and is driven at half engine speed directly off the rear end of the main oil pump spindle, the petrol pump driving shaft being coupled to the oil pump spindle by a dog clutch. The installation of the petrol pump is clearly shown in the general arrangement drawing of the engine, and the details of the petrol supply system are shown in the diagrammatic drawing (Fig. 26).

Regarding the installation of the petrol supply system to the petrol pump in the machine, it is assumed that the main petrol tank is provided with the ordinary float regulator, which has always been fitted inside the petrol tanks for regulating the supply through the petrol pumps: but owing to the fact that the machines from which these new Maybach engines were taken are completely destroyed no information regarding the construction and installation of the petrol tanks is available. In the Rumpler machines fitted with the 260 h.p. Mercedes engines two petrol tanks are fitted. The main tank is in the centre of the fuselage behind the pilot's seat, and the auxiliary tank is situated under the pilot's seat.

(To be continued.)

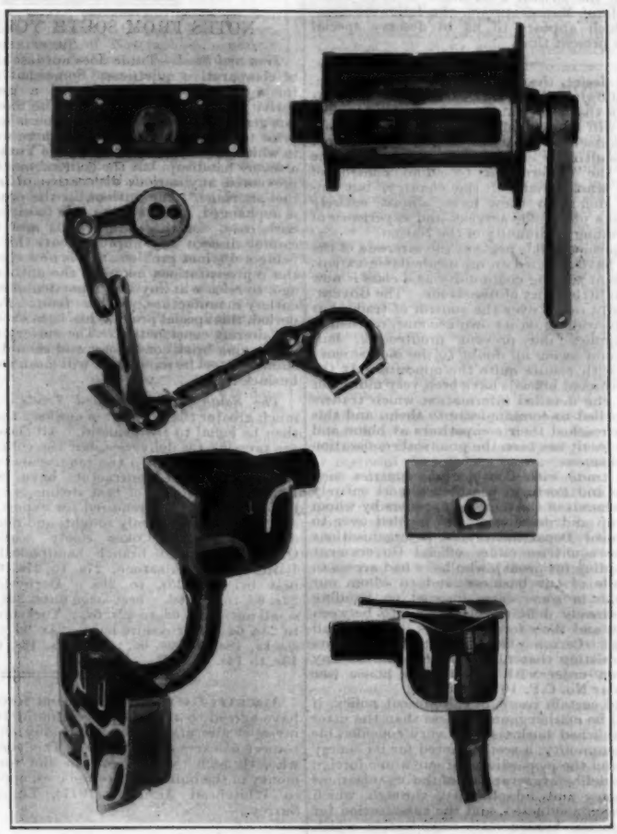


FIG. 37. THE THROTTLE AND JETS DISMANTLED; AIR SHUTTER; AND SECTIONAL VIEWS OF PETROL RESERVOIRS IN CARBURETTORS.

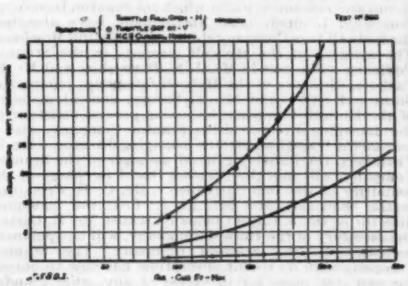


FIG. 39. DIAGRAM OF COMPARATIVE TESTS OF CARBURETTOR.

THE COAL RESOURCES OF BRITAIN AND GERMANY.—Speaking at the Exhibition of Scientific Apparatus, at King's College, last week, Professor H. Louis said that much capital had recently been made out of the fact that the coal resources of Germany were 2½ times as great as those of the British Islands. But we were awaking to the fact that the resources of the Empire could be and ought to be pooled for the benefit of the whole Empire. Add the coalfields of South Africa, Canada, India and Australia to those of the British Islands, and we should get total resources considerably more than three times those of Germany and her allies. Of far more immediate importance was the question of the actual coal production. Of the estimated coal resources of Germany, about three-fourths were returned as only probable, and only one-fourth as actually proved, whereas of the British coal reserves, two-thirds were actually proved. As regarded output, which was the thing that mattered for the moment, the output of the British Isles was still greater than that of the whole of Germany, and this was a matter which vitally affected the conduct of the war.

BOYS' WELFARE ASSOCIATION.—The Boys' Welfare Association, which has been established for the encouragement and assistance of employers in promoting the welfare of their young male employees, has already made substantial progress, many of the principal engineering firms having joined as members, while applications or inquiries for particulars of the movement are coming in every day. An influential council has been formed consisting of Sir W. Beardmore, Bart. (W. Beardmore and Co., Limited), chairman; Mr. W. H. Allen (W. H. Allen, Son and Co., Limited); Sir R. Baden-Powell, K.C.B., K.C.V.O. (Boy Scouts Association); Mr. F. S. Button (A.S.E.); Sir G. F. Carter, K.B.E. (Cammell, Laird and Co., Limited); Sir K. T. Crossley, Bart. (Crossley Brothers, Limited); Mr. J. Denny (W. Denny Brothers, Limited); Mr. H. C. Dickson (Halesowen Steel Company, Limited); Mr. C. G. Gilbertson (W. Gilbertson and Co., Limited); Major-General Sir E. P. C. Girouard, K.C.M.G., D.S.O. (Sir W. G. Armstrong, Whitworth and Co., Limited); Sir Alexander Gracie, K.B.E. (Fairfield Shipbuilding and Engineering Company, Limited); The Right Hon. J. Hodge, M.P. (Minister of Pensions); Sir G. B. Hunter, K.B.E., D.Sc. (Swan, Hunter and Wigham Richardson, Limited); Mr. S. Mavor (Mavor and Coulson, Limited); Mr. S. Osborn (S. Osborn and Co., Limited); Sir Herbert Rowell, K.B.E. (R. and W. Hawthorn, Leslie and Co., Limited); Mr. Douglas Vickers (Vickers, Limited). The Hon. Treasurer is Mr. S. E. Alley (Sentinel Wagon Company, Limited), and the Rev. Robert R. Hyde is the director. The offices of the association are at Sanctuary House, Tothill-street, S.W. 1, where all inquiries should be addressed.

TRADE AND COMMERCE.

We have received from Mr. Charles T. Evennett, the secretary of the British Federation of Iron, Steel, Tinplate and Metal Manufacturers, the following communication, which appears to us to deserve special attention at the present time.

"My council desire, through your valuable medium, to place the following statements before the public at large, in the hope that the vital importance of the subject they deal with will be realised before it is too late, and the Nation finds itself committed to a policy little short of suicidal in its ultimate effects. The exigencies of the war have led the Government to adopt control of practically the whole trade of the country, but unfortunately in doing so they have almost entirely neglected to make use of the services and experience of the merchant trading community of the Nation.

"As a consequence of this neglect, the interests of the public at large have suffered to an incalculable extent, while the merchant trading community as a class is now facing a position little short of disastrous. The Government has not only taken over the control of trade, but has also taken to trading on its own account, ostensibly to regulate supplies and prevent profiteering, but, unfortunately—and owing no doubt to the inexperience of its officials—with results quite the opposite. At the same time Government officials have been very indiscreet in dealing with the detailed information which traders have been compelled to communicate to them, and this information has reached their competitors at home and abroad, and the result has been the practical confiscation of their entire business.

"Our export trade with Continental countries such as France, Italy and Portugal has been almost entirely taken out of the hands of the merchant traders by whom it was worked up and developed, and handed over to British Government Departments and to organisations formed in those countries under official Government sanction (but trading for profit), who have had access to the fullest details of our business, and to whom our Government have in some cases insisted on handing over contracts already definitely entered into between British exporters and their foreign clients (including all profits accruing). Certain Government Departments are even now insisting that no consumer shall on any account place an order with a merchant house (see Admiralty circular No. C.P. 161579/18).

"The sure and certain result of the present policy, if persisted in, will be neither more nor less than the utter ruin of the established business of a very considerable section of the community, a section noted for its energy and enterprise, and the jeopardising of our whole foreign commerce by the deliberate scrapping of the organisations of proved efficiency and adaptability through which it has hitherto been conducted, and the substitution for these of an immense bureaucratic organisation which will certainly kill all individual initiative and enterprise, and by its cast-iron methods drive our overseas customers *nolens volens* into the arms of our competitors.

"Now the restoration of national financial position after the war will depend entirely upon the recovery of our export trade and its vast extension. No bureaucratic organisation can ever handle this trade with the efficiency and ability of the merchant traders, whose wide experience of foreign markets and the special handling which they require both in respect of the class of merchandise to be supplied and the methods of finance, &c., is an asset of incalculable value to the Nation, and which the Nation as a whole must see is not scrapped to its own irremediable and inestimable loss.

"The iron, steel, tinplate and metal merchants of this country, recognising the serious state into which the Nation's trade is surely drifting, have formed themselves into a federation in order, by every means in their power, to endeavour to remedy this state of things. They invite the other classes of the merchant trading community to form similar federations with the same objects, and to join in the united effort to remedy and prevent as far as possible the fatal ultimate results which are inevitable unless the methods adopted by our bureaucratic Government Departments are immediately corrected.

"My council considers that these Government Departments, which were set up for war conditions only (and which would not otherwise have been tolerated for a week), desire if possible to perpetuate their existence, and if they are allowed to have their way now they will wreck the whole system upon which our world-wide trade has been built up and established.

"My council fears that our Government officials are obsessed with the idea that the large organisations of manufacturers in Germany and the United States of America are examples to be copied in this country, forgetting that these were not imposed by the State, but were the outcome of the uncontrolled efforts of the commercial community, and that these organisations never attempted to interfere with the established channels of trade, but recognising their very high value, made the fullest possible use of them.

"Undoubtedly an immense amount of man-power and expenditure could have been saved to the State during the war if, from the outset, the merchant traders of the country had been taken into consultation by the Government equally with the manufacturers and Labour, and had been represented on the various committees appointed by the Board of Trade, the Ministry of Munitions and the Ministry of Reconstruction.

"Unfortunately this has not been done, and merchant traders' interests are practically unrepresented on these various committees, which are composed almost entirely of civil servants, and representatives of high finance, manufacturers and Labour. Unless this state of things is altered and their assistance is promptly asked and obtained by the State, the prospects for British trade and commerce after the war are almost hopeless."

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Trade does not lose the characteristic of comparative quietness. Somewhat accelerated calls for munitions have introduced a greater degree of activity into some branches of the Sheffield industries, but generally speaking the position is much the same as prior to the August holidays. There were departments in which the recent stoppage in the Yorkshire pits caused a severe handicap, but the colliers' quick return to work prevented any serious dislocation of industry through fuel shortage. The outlook in the crucible steel trade is unchanged, makers being able to satisfy current needs with ease. In the rolling mills and forges, too, one cannot discern any improvement, the labour shortage being a distinct problem. It is now thought likely that the representations made to the authorities some time ago, to release at any rate a portion of stainless steel for cutlery manufacture, will bear fruit. For a considerable period, this special product has been exclusively reserved for aircraft construction. The cutlery trade at present is enjoying brisk conditions, and should the embargo on stainless steel be removed it will mean considerably more business.

The South Yorkshire Coal Trade.—If output were much greater than it is, it is unlikely that it would even then be equal to the demand. All classes of consumers are pressing for deliveries, but the colliery owners have nothing to spare when the requirements of the Government and of the contractors have been dealt with. Inland consumption of best steams is considerable, and large quantities are required for export. Cobbles, nuts and slacks are all keenly sought, and household sorts are distinctly short. Cokes easily realise top prices. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d* to 22*s* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

Aircraft Capital.—The Inland Revenue authorities have agreed to allow the retention of 18 per cent upon invested aircraft capital before any charge is made in respect of excess war profits. This concession to those who, through their patriotism and foresight, invested money in the building of aeroplanes, applies in particular to Whitehead Aircraft (1917), Limited, Richmond, Surrey.

Personal.—Mr. D. G. Robertson, who has been sales manager of Messrs. George Ellison, for the past 9¼ years, has now vacated the position, on his appointment as assistant general manager.—Referring to the recent announcement under which the Stanton Ironworks Company, Limited, near Nottingham, have absorbed the Holwell Iron Company, Limited, of Melton Mowbray. The merging of the Holwell interests in the Stanton Company will result in Mr. J. N. Derbyshire and Mr. F. Carbutt, directors of the Holwell Company, joining the Stanton Board; and Mr. T. Sarson, general manager of the Holwell Company, becoming general assistant to the managing director of the Stanton Company, with a seat on the board as assistant managing director. Mr. F. Chambers, the foundry general manager of the Stanton Company, will join the Stanton Board in charge of the foundries of the two businesses. Mr. C. R. Crompton is the chairman, and Mr. E. J. Fox, the managing director of the Stanton Company, whilst Mr. E. Carter, the secretary of the Holwell Company, will be appointed secretary to the Stanton Company. The Stanton Company with its recent absorption, has now an output for cast-iron pipes far in excess of any other foundry in Great Britain, whilst their capacity for pig-iron is in excess of any other producer in the Midlands.

Rewards for Inventors.—It appears that Mr. John Scott, of Edinburgh, Scotland, bequeathed a sum of money to be held in trust by the city authorities of Philadelphia, U.S.A., the interest on which is to be used for rewarding or encouraging "ingenious men and women who make useful inventions." During the past twenty years some 900 "discoveries, processes and inventions" have been investigated. The Franklin Institute for the Promotion of the Mechanic Arts, well known to British engineers through its excellent technical "Journal," conducts some of the investigations and recommends awards of a medal and money premium. In addition to the consideration of the merits of an invention as a piece of mechanism an investigation is made by the City Committee on Service and Arts into the practical and social effects of the invention; for example, if the product is a food preparation, whether the food, as food, compares favourably with that produced by the commonly-used methods or machines; or, again, whether the invention enables a peculiarly situated locality to satisfy its requirements in an improved or more economical manner. The investigation also extends so far as taking evidence from those who have bought and used the invention. We are not aware of any similar trust fund for encouraging ingenious and useful invention in this country. This note may suggest a way out of their difficulties to those who are at a loss to spend or bequeath money to the best social advantage.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—September allocations of Cleveland foundry iron for home consumption are quite satisfactory. Production of foundry iron has shown some improvement, and thus prospects are regarded as slightly more favourable to consumers. At the same time, prevailing conditions prohibit the supply of foundry pig-iron to other than Class A consumers. The Ministry are showing a disposition to ship more iron to the Allies, even at the expense of home consumers. Iron shipped to Scotland under the scheme of official chartering is not on an extensive scale. For such iron as can be delivered ample supply of trucks are available, and thus there is no immediate need to resort to the more costly method of shipment, although it is understood that any increased cost will be met by subsidy. Shipments of Cleveland iron are well maintained. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.* and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 119*s.*, and No. 1 is 124*s.*

Hematite Iron.—Demand for East Coast hematite is unabated. The heavier shipments tend further to restrict the quantities available for home consumption, and but for the large and increasing use of basic iron, and scrap in the manufacture of steel, the situation would be exceedingly stringent. As it is, supplies of hematite are passing from hand to mouth. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—Though makers are hampered by the fuel situation, manufacture of finished iron and steel is on a very heavy scale. Under the system of control, ample material for the shipyards is assured, and producers of such commodities have their work well in hand, but in other branches deliveries are not so readily obtained, and any one with a new order to place, needs a high priority certificate to have any prospect of supply. Quotations, all round, are very strong, but unaltered. To home customers the following are among the principal market quotations:—Common iron bars, 14*l.* 15*s.*; best bars, 15*l.* 15*s.*; best best bars 16*l.* 15*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.* Export prices are not fixed, but they are approximately 40*s.* to 60*s.* above home quotations.

Shipments of Iron and Steel.—According to official statistics shipments of pig-iron, manufactured iron and steel from the ports of Middlesbrough for August totalled 65,484 tons, which are the heaviest recorded since August, 1917, when the loadings reached 83,463 tons. This year's July shipments were returned at 56,866 tons, so that August clearances showed an increase over the previous month of 8,618 tons. August loadings of pig-iron amounted to 48,593 tons, as against 49,110 tons in July—a slight drop—but the total of 16,891 tons of manufactured iron and steel was the largest since January last, the July total being only 7,756 tons. Shipments of pig-iron to foreign ports last month amounted to 41,712 tons, as compared with 41,439 tons in July, and despatches coastwise were returned at 6,881 tons, as against 7,671 tons in July. Only 589 tons of manufactured iron were cleared in August, but these exceeded the July shipments by 372 tons. Loadings of steel last month reached 16,302 tons, or more than double the July total of 7,384 tons.

Coke.—Every effort is made to maintain supplies of coke to the blast furnaces. Average furnace kind is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens.

The Tanks.—Speaking at Lincoln last week, Major-General Seeley referred to the important part now being played in warfare, by the tanks. He said that in Lincoln was first conceived, bred and created, that great engine of war which had revolutionised the modern battlefield—the tank. As he came into that room he was handed a copy of the latest communiqué from the Western front, and he read the sentence 'Tanks have taken an active part on all possible occasions, and have rendered very valuable and gallant service." That was good reading for all men, and especially in Lincoln, where so many of the inventive minds, best brains and muscles of the citizens had been engaged in perfecting that great modern arm. He made no secret that he was there not only to open that exhibition. He had other official duties to perform, but he could not refrain from saying that he did believe the invention of the tank and its perfection had done more to bring the war to a happy conclusion, as it would be brought, and more, above all, to save the lives of our brave men, than any other single thing. A brilliant soldier had computed from the most exhaustive examination into comparative statistics of battles before and since the tanks were introduced that the presence of 36 tanks on the battlefield, properly disposed, meant the saving of 1,000 lives of our soldiers. When people in Lincoln were wearying of their work and long hours that was a most heartening thought. He had been spending most of his time in service across the seas, and there he hoped to return when his present work was done. He was glad to be back for a short time to join in that great effort and to bring home to them the importance of encouraging all inventive and mechanical genius to the crushing of the arrogance and tyranny of Prussia.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—There is now a better supply of most classes of coal on the market, and the outlook generally is improved. With the practical termination of the miners' holidays there is an increase of production, while the demand on shipping account is not so pressing as has recently been the case. The result is that salesmen are a little relieved by the lifting of the pressure put upon them from all quarters. The best steam coals have been fairly comfortably placed. A good deal of interest has centred in the decision of the Ministry of Munitions to subsidise the production of coke in the South Wales coalfield to the extent of 5*s.* per ton. On other occasions when cost of production of coke has been increased by enhanced coal prices, the practice of the Ministry of Munitions has been to increase the prices of coke proportionately; but that practice necessarily involved the revision of the list of all regulated iron and steel prices, and the authorities have now considered it a more expedient course to avoid such a disturbance again by meeting the legitimate claims of the coke manufacturers by a subsidy. The concession is regarded as, on the whole, a fair one, and in so far as it can be regarded as an addition to scheduled coke prices it will increase the price for furnace coke from 37*s.* 6*d.* to 42*s.* 6*d.* and that of foundry coke from 50*s.* 6*d.* to 55*s.* 6*d.* It may be added that the subsidy does not apply to coke for export, for which the scheduled price is 54*s.* 6*d.*

Newport.—There is an increased supply and a slightly less demand for all classes of Monmouthshire coals, especially for export purposes. There is an accumulation of small coal, and at the present rate the supply will soon outrun the demand. There is a good supply of pitwood and of iron ore.

The Price of Admiralty Coal.—When an intimation was received from the Coal Controller's Department, at the end of last week, that the Admiralty had agreed to pay an increase of 1*s.* 6*d.* per ton on coals supplied as and from June 30, the colliery people concerned were very much perturbed. The increase was stated to be made to meet the increase in the cost of production caused by the miners' war wage, &c., but this was considered inadequate. Representations were, therefore, instantly made to the authorities, and it has now been explained to the Admiralty collieries that the 2*s.* 6*d.* per ton increase in price conceded by the Controller under his directions of June apply to coals supplied to the Admiralty as well as to oversea consumers, and that, consequently, Admiralty coal prices have been advanced by 4*s.* per ton over those which have been paid during the past twelve months. But even this concession leaves a difference of 4*s.* 6*d.* per ton and more between Admiralty prices and those scheduled in the Controller's directions, and representations are again being made to the authorities for further relief as from January 1 last, and not simply from the dates of the recent order. It is pointed out that the cost of production, calculated on output of large coal, is at present in the neighbourhood of 35*s.* per ton f.o.b., and that owing to the commandeering of the outputs of the Admiralty collieries, the latter are given practically no opportunity to profit from the higher export price ruling on the market to-day.

SMART SHIPBUILDING WORK AT BELFAST.—A remarkable achievement has just been performed at Messrs. Harland and Wolff's works at Queen's Island, Belfast. The War Snake, a standard ship, gross tonnage 5,150, and deadweight tonnage 8,000, was launched on August 22, and performed her trials on the 29th. The whole work of fitting the engines and boilers and preparing the vessel for sea had been accomplished in six working days, instead of six weeks, the time usually taken in vessels of this type. The War Snake, which is 400 ft. long, was laid down on March 14, and is thus ready for service in less than 5½ months from the beginning of the work.

THE LONDON SCHOOL OF ECONOMICS.—Arrangements have been made for the delivery, at the London School of Economics, during the session 1918–19, of a series of lectures on Railways and Cognate Subjects. Amongst the lecturers is Mr. Philip Burt, formerly deputy manager of the North-Eastern Railway. Mr. Burt will deliver five courses of lectures. In the elementary course he will discuss "The Railway System as a Wealth-creating Machine" and "Elementary Problems in Transportation." In the advanced course the lectures will be devoted to a consideration of "The Principal Factors in Railway Operating" and "The Basis of Railway Rates and Charges." A fifth series of lectures will deal with "The Value of Accurate Costs Figures in Railway Management."

ENGINEERING IN MESOPOTAMIA.—Lowell, in his Biglow Papers, once observed that civilisation does at times "get forward somehow on a powder cart." An instance of this is afforded by the despatch from General Marshall published last week. To ensure a perfect system of communication in the new forward area considerable work was necessitated. The main canals, *i.e.*, Khalis, Mansuriya, Khorassan, Mahrut, Haruniya, and Rus, as well as their numerous distributaries, were rapidly bridged—often at more than one place—and this mobile bridging equipment was subsequently replaced by more permanent structures capable of carrying heavy loads. Seventy-five bridges of various sizes were built in this area alone, and the Jebel Hamrin, which before our occupation was a roadless tangle of hills, was gradually pierced by a very complete and convenient number of roads suitable for wheeled traffic. These road constructions and improvements will obviously be of permanent value.

NOTICES OF MEETINGS.

THE INSTITUTION OF MINING ENGINEERS.—Twenty-ninth annual general meeting, Friday, September 13:—11 a.m.: The members and visitors will be received in the Lecture Theatre, University College, Nottingham, by the Mayor and Sheriff of Nottingham, and the President of the Midland Counties Institution of Engineers. 11.15 a.m.: The twenty-ninth annual report of the council will be read; the names of the officers for the year 1918–19 will be announced; the Institution auditors will be elected; the newly-elected president will take the chair, and will deliver his "Presidential Address"; the Institution medal for the year 1917–18 will be presented to Mr. Charles Edward Rhodes. The following papers will be read, or taken as read: (1) "A Method of Determining the Magnetic Meridian as a Basis for Mining Surveys," by Mr. T. Lindsay Galloway (Mr. Galloway will give a practical demonstration of the method described); (2) "Digest of the First Report of the Mine Rescue Apparatus Research Committee," by Mr. David Penman; (3) "The Chance Acetylene Safety-lamp," by Mr. William Maurice. (4) "Recent Developments in the Coalfields South of Sydney, New South Wales," by Dr. J. R. M. Robertson. The following papers, which have already appeared in the Transactions, will be open for discussion: (a) "Terrestrial Magnetism in Relation to Mine Surveying," by Dr. Charles Chree, F.R.S., vol. lv, page 223; (b) "The Effects of Dust-inhalation," by Mr. John Scott Haldane M.D., F.R.S., vol. lv, page 264; (c) "The Origin of Blackdamp," by Mr. J. Ivon Graham, vol. lv, page 294; (d) "The Flow of Air through Small Coal and other Broken Material," by Mr. J. T. Storrow, vol. lv, page 313. 1 p.m. to 2.30 p.m.: An adjournment will be made for luncheon. 5 p.m.: The general meeting will be closed. Owing to the war it has been decided not to hold the usual dinner this year.

IRON AND STEEL INSTITUTE.—Thursday and Friday, September 12 and 13, at the Institution of Civil Engineers, Great George-street, Westminster:—Thursday, September 12: 10.30 a.m., general meeting of members. Scrutineers will be appointed for the examination of voting papers for election of new Members of the Institute. A selection of papers will be discussed (Nos. 4, 13, 15, 11). 2.45 (afternoon session): papers Nos. 3, 10, 17, will be discussed. 4.30 p.m.: The meeting will be adjourned to 10 a.m. on Friday, September 13. Friday, September 13:—10 a.m.: General meeting of members. A selection of papers will be discussed (Nos. 8, 1, 12, 5). 2.45 (afternoon session): Papers Nos. 7, 14, 16, will be discussed. The following is the list of papers that are expected to be submitted: (1) "Principles of Open-Hearth Furnace Design," by Mr. C. H. F. Bagley; (2) "The Rate of Change at 100 deg. C. and at Ordinary Temperatures in the Electrical Resistance of Hardened Steel," by Mr. E. D. Campbell; (3) "Some Experiments on the Reaction between Pure Carbon Monoxide and Pure Electrolytic Iron below the A1 Inversion," by Mr. H. C. H. Carpenter and Mr. C. Coldron Smith; (4) "Influences of Hot Working on the Qualities of Steel," by Mr. G. Charpy; (5) "The Casting of Steel in Ingot and other Moulds," Mr. J. E. Fletcher; (6) "Notes on a Telescopic Focussing Apparatus for Photomicrography," by Mr. A. F. Hallimond; (7) "Case-Hardening Practice," by Mr. D. Hanson and Mr. J. E. Hurst; (8) "Use of Bosh Tuyeres in the Blowing of Basic Pig-Iron," by Mr. J. S. Hollings; (9) "On Magnetic Analysis as a means of Studying the Structure of Iron Alloys," by Mr. K. Honda; (10) "Prevention of Growth in Grey Cast-Iron," by Mr. J. E. Hurst; (11) "Standardisation of Tests for Refractory Materials, by Mr. Cosmo Johns; (12) "The Utilisation of Waste Heat from Open-Hearth Furnaces for the Generation of Steam," by Mr. T. B. Mackenzie; (13) "Influence of Elements on Tenacity of Basic Steel," by Mr. A. McWilliam; (14) "Chemical Standards and their Bearing on the Unification of Analysis," by Mr. C. H. Ridsdale and Mr. N. D. Ridsdale; (15) "Hardness Testing: Relation between Ball Hardness and Sclerocope Hardness," by Mr. A. F. Shore; (16) "Phosphorus in Malleable Cast-Iron," by Mr. J. H. Teng; (17) "Notes on the Warping of Steel through Repeated Quenching," by Mr. J. H. Whiteley.

THE JUNIOR INSTITUTION OF ENGINEERS; NORTH-EASTERN SECTION.—Tuesday, September 10, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle-on-Tyne. Paper on "Electric Furnaces," by Mr. C. H. Blenkinsop.

INSTITUTE OF METALS.—At the autumn meeting of the above Institute the following communications are expected to be submitted in the order given:—September 10 (evening session, 7.45 p.m. to 10 p.m.), the following papers: (1) "The Effect of Progressive Cold-Work upon the Tensile Properties of Pure Copper," by Mr. W. E. Alkins, Student Member (Manchester); (2) "The Resistance of Metals to Penetration under Impact, including a Note on the Hardness of Solid Elements as a Periodic Function of their Atomic Weights," by Professor C. A. Edwards, D.Sc., Member of Council (Manchester). September 11 (afternoon session, 4 p.m. to 6 p.m.) the following: (3) Paper, "Grain Growth in Metals," by Mr. Z. Jeffries, D.Sc., Member (Cleveland, Ohio); (4) Note, "Rapid Decrystallisation in Deformed Non-Ferrous Metals," by Mr. D. Hanson, M.Sc., Member (Teddington); (5) Note, "The Influence of Impurities on the Mechanical Properties of Admiralty Gun-metal," by Mr. F. Johnson, M.Sc., Member (Birmingham); (6) Note, "Rapid Method of Estimating Phosphorus in Bronzes," by Mr. T. E. Rooney, Member (Teddington); (Evening session, 8 p.m. to 10 p.m.): (7) Note, "A Peculiar Case of Disintegration of a Copper-Aluminium Alloy," by Mr. R. Seligman, Ph.D., and Mr. P. Williams, Members (London); (8) Paper, "Annealing Cold-Rolled Aluminium Sheet by Abbreviated Exposures at Various Temperatures," by R. J. Anderson, B.Sc., Met.E., Member (Cleveland, Ohio); (9) Note, "Alloys of Copper and Zinc: An Investigation of Some of their Mechanical Properties," by Mr. F. Johnson, M.Sc., Member (Birmingham); (10) Note, "Use of Liquid Fuel in the Foundry," by Captain A. E. Plant, Member (on active service).

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Government control and Government demands dominate the production of steel in the Clyde area, and orders never were more plentiful, with the result that all the available plant is in constant motion. One point in favour of the manufacturers is that so much of the material required is practically of the more ordinary sizes that special rollings are not as necessary as would otherwise be the case. This is of considerable advantage when taken into account with the inadequate supplies of raw material, the all too evident shortage of skilled labour, and the difficulties connected with the mining and the transport of coal. With the exceptionally heavy demand for manufactured and semi-manufactured steel by the shipbuilding yards, the munition factories and the general engineering works, only a very small percentage of the production is available for export. While rates remain at a steady level there is every indication that an advance in prices is imminent.

Malleable Iron Trade.—The position of affairs in the malleable iron industry grows more intense—orders continue to flow in, but so urgent is the demand for war material that only those accompanied by a high priority certificate can be undertaken. It means the dropping of a considerable amount of ordinary commercial business, but the claims on war account are of paramount importance and everything else must stand aside meantime. Both in the iron and the steel departments makers are doing all in their power to speed up production and maintain the output at the required level, and in doing this every available mill is employed to its fullest capacity. The recent advance in price has in no way interfered with the demand for malleable iron, the overseas claims being so urgent and so vital that price is of not the slightest consideration. The orders on hand for agricultural work, for railway work and for bolt and nut iron, are being executed with the least possibly delay.

Scotch Pig-Iron Trade.—There is a very active demand for all grades of pig-iron, and although some are more scarce than others, the system of control at present in operation tends to make things go as smoothly as could be hoped for under the very exceptional circumstances now existing. Control has meant the distribution of the output in as equitable a manner as possible, the more urgent claims receiving the first consideration, and by limiting the larger orders to more moderate dimensions a wider area has been covered. As the home demands considerably exceed the supply, little export is being permitted.

Clyde Shipbuilding.—The activity in the Clyde shipbuilding yards continues to be most pronounced, and some fine records have been established. Within the past month, for instance, Messrs. William Hamilton and Co., of Port Glasgow, have handed over three new vessels, two of these large freight carriers. One of these, again, is for the meat traffic, with a tonnage of 10,000 tons gross, while the other is an ordinary cargo vessel of 8,000 tons. In three weeks the riveters completed by hand the entire shell of an 8,000-ton vessel ordered for the Clan Line, into this 100,000 rivets having been driven in 18 working days. In a neighbouring works, that of Messrs. J. G. Kincaid and Co., Greenock, another feat was recently carried out, an 8,000-ton steamer being engined and boilered in 2½ working days. This firm is also putting in some exceptionally good work in connection with the fitting-out of standard oil tankers.

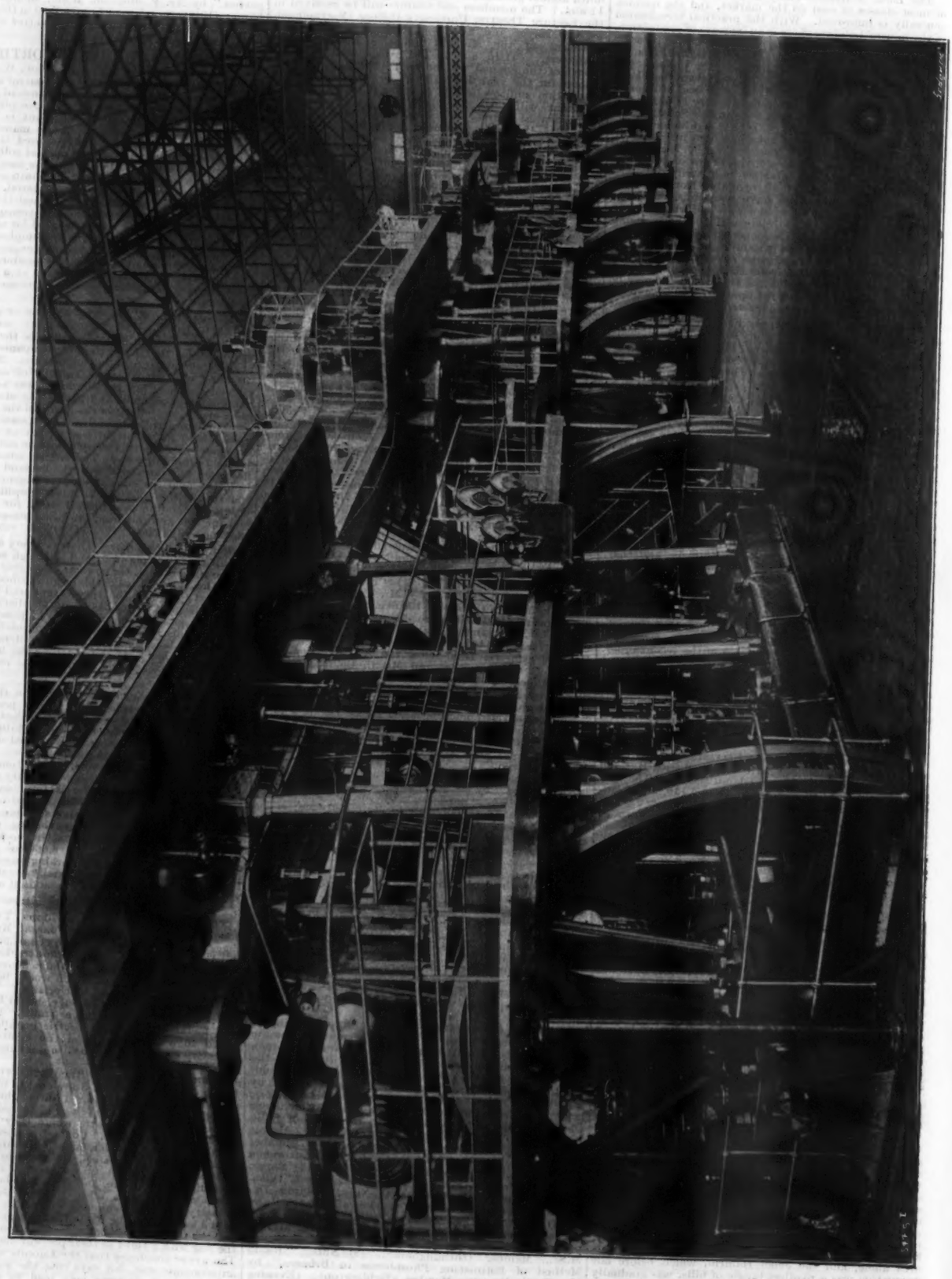
ELECTRIC TRACTION FOR GOODS TRAINS.—In an article in the *Electric Railway Journal*, Mr. G. M. Woods suggests a method by which he claims goods trains can be hauled electrically over the same tracks as electrically-propelled passenger trains, without increasing the peaks of load beyond the limit which would be attained with the passenger services alone electrified. To this end he suggests that the goods haulage should be concentrated on the basis of light passenger traffic. In this way the load factor of the whole electric installation would be raised to a maximum, and the capital cost of the necessary equipment reduced to a minimum.

GERMANY'S PLANS FOR RECONSTRUCTION.—According to the *Vossische Zeitung*, State control of German trade and industry will be required during the reconstruction period because of the shortage of tonnage and in order to direct German exports where they are needed, to improve the exchange. Control is specially indicated for textiles, oils, rubber, hides and shipping; nothing is said about iron, steel, or engineering. Economic boards are to be set up to control exports, foreign exchange and tonnage, and there will be a Government tonnage distribution office for the German shipping industry. German shipping companies are now being paid a subsidy by the State for tonnage lost in the war, and the Germans reckon that at the worst they will end the war with a third of their pre-war mercantile marine. The writer concludes that the Entente will not carry on an economic war, but says that the world shortage of materials and shipping may lead to Allied measures which, under the guise of reconstruction policy, actually amount to an economic war.

QUADRUPLE-EXPANSION SEWAGE PUMPING ENGINES; CAIRO MAIN DRAINAGE.

CONSTRUCTED BY MESSRS. JAMES SIMPSON AND CO., LIMITED, ENGINEERS, LONDON AND NEWARK.

(For Description, see Page 251.)



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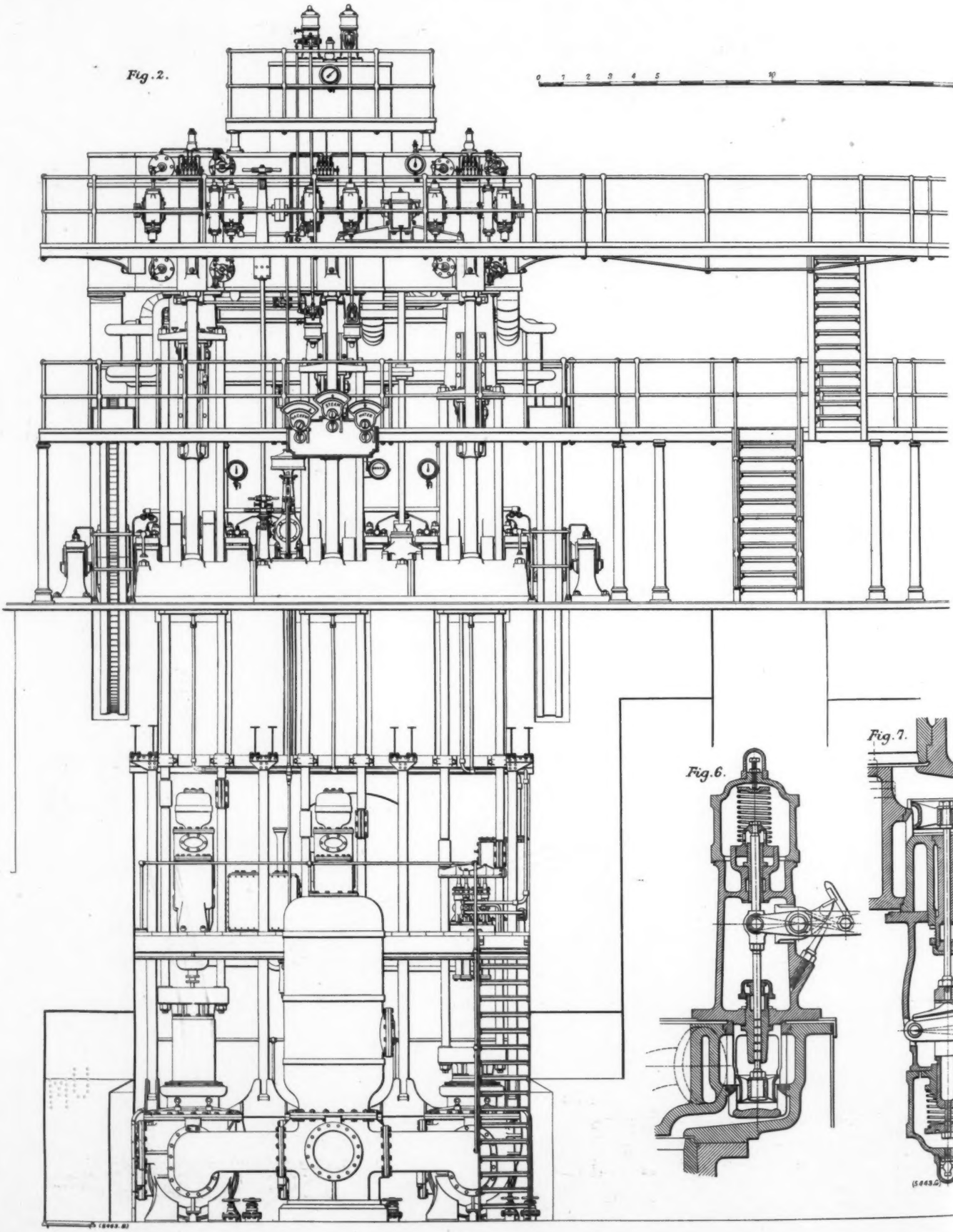

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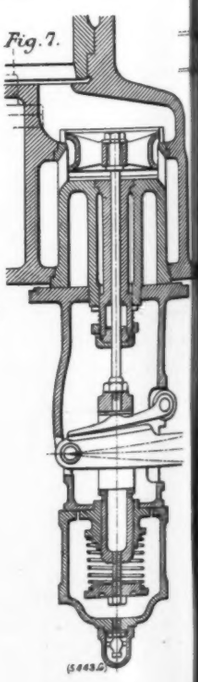

PUMPING ENGINES; CAIRO MAIN DRAINAGE.

ON AND CO., LIMITED, ENGINEERS, LONDON AND NEWARK.

(Description, see Page 251.)

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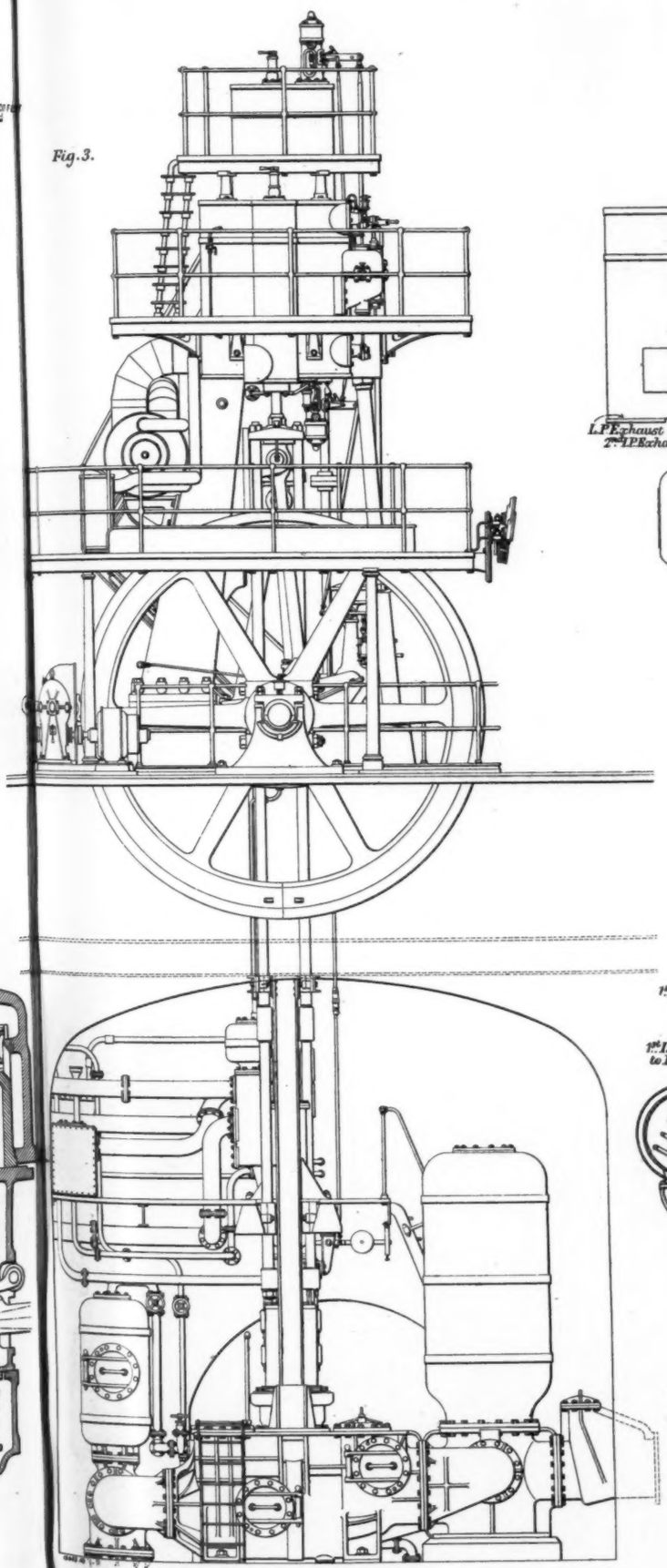

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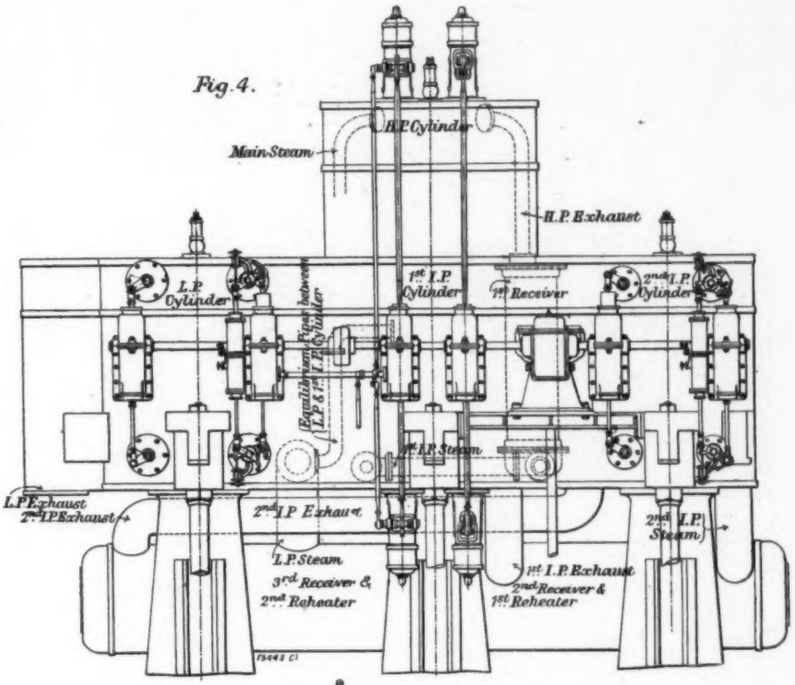

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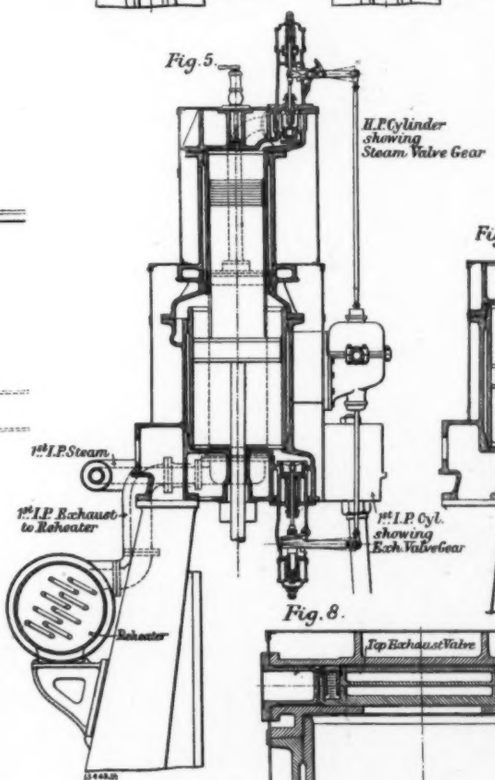

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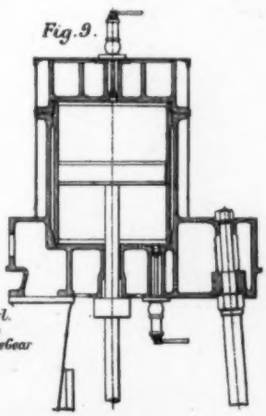

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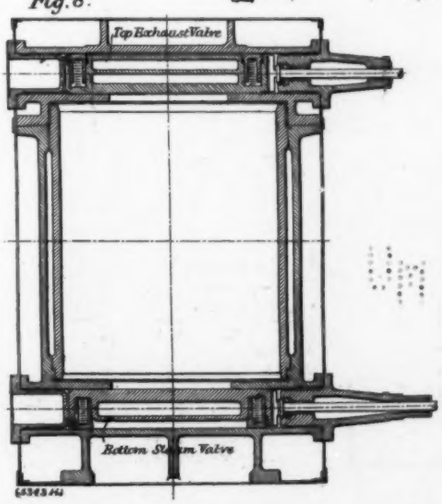

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—5062 and 8596 GERRARD.

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NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents after June 24th will not have copies for chance customers, therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 259.

ENGINEERING.

FRIDAY, SEPTEMBER 6, 1918.

SCIENTIFIC AND INDUSTRIAL RESEARCH.

UNDER serious financial stringency, Egypt found, in 1885, one million sterling for expenditure under scientific direction in promoting the industry of that country. In 1915, under conditions also of great financial stringency, Parliament provided 1,000,000*l.* for expenditure in promoting by scientific investigations, the industrial interests of this country, and there is reason to hope that the venture will ultimately prove in every way as profitable as it did in Egypt, where the return has been nothing less than astounding. In our own case, the administration of the fund thus taken definitely "out of politics," was entrusted to the advisory council of Scientific and Industrial Research, whose report for the year 1917–18 was published last week. Perhaps the principal event of the year, as recorded in the report, has been the definite taking over from the Royal Society of all financial responsibility for the National Physical laboratory. The necessities of the war have made it essential to sever the relationships which had slowly developed between the laboratory and our industries. By far the larger proportion of the income of the laboratory was derived from fees for work done for private firms, and as this work has had to be almost entirely stopped in order to attend to the problems brought forward by the naval and military authorities, there was a great danger of a most serious deficit in the income of the establishment whenever hostilities should cease. The Royal Society felt that it could not accept this possibly extremely heavy financial responsibility, and the arrangement above referred to was accordingly consummated. One of the immediate difficulties which the advisory council have had to meet in this connection has been the inadequacy of the salaries paid to the technical staff. Conditions at the laboratory are pleasant, and the work highly interesting, so that appointments to the staff have had considerable attractions for clever young men, but the difficulty is that the better these may be, the greater are the inducements likely to be offered of better-paid work elsewhere. In this way, when salaries are inadequate, there is a danger that all the exceptionally able men will be sorted out, and merely the mediocrities left behind. The Treasury has now sanctioned an amended scheme of salaries, so that this risk is, for the moment, averted. There are indications, however, though the financial advisers of the Government have yielded for the time, that the Treasury lives in hopes that previous conditions will be re-established after the war, and that it may be again in a position to obtain at quite inadequate salaries the services of highly-cultured and expensively-trained scientific men. In short, in accepting the revised scale of salaries, the Treasury reserves the right to reconsider the whole matter when peace is proclaimed.

Further progress has been made during the year in the establishment of associations for industrial research. To facilitate the incorporation of bodies of this type, the council have had prepared drafts of articles of association, which may be taken as models, and the adoption of which, as the clauses have already been approved by the Board of Trade, will save time and expense. One of the difficulties met with in this connection has been the reluctance of certain of these associations to come in any way under governmental control. Rather than risk interference by the official finger, some of these researches associations have preferred to dispense with financial help. In particular, objection has been taken to two clauses incorporated in the conditions under which grants are made. The one clause provides that the results of the investigations carried out with the aid of grants from the council shall be communicated in the first place to this body, and that the council shall then determine, in the national interest, to what extent and under what conditions the results shall be made available. It is now explained that this clause is, in part, intended to prevent results of commercial value being made available in other countries to the detriment of our own. The Government can, it is claimed, prevent leakage better than any private association can do. In the second place, it is held that results obtained with national funds must not be confined to the benefit of individual firms to the detriment of others willing and able to take up the new processes.

The other clause to which exception has been taken reserves the right to the council to determine in whom patents and the like shall be vested, and to proportion the benefits arising therefrom. It is explained that the object of this clause is to secure a generous reward to the actual discoverer or inventor. This is a most worthy aim, but the problems involved, will often prove of extreme difficulty. In general there is a very difficult step between a laboratory research and its commercial application. No doubt a somewhat lower grade of intelligence is required to effect this passage than to make the original discovery, but great industry must be exercised and in general heavy financial commitments risked. To apportion pecuniary rewards to the various interests concerned is accordingly far from an easy undertaking.

Stress is laid in the report on the importance of including some representatives of labour on the council of all research associations. This should prove highly advantageous from more than one point of view. Some experience of the methods of science would supply an extremely serious defect in the education of the average labour leader whose usual stock in trade consists of certain plausible *à priori* hypotheses and logical deductions therefrom. Science also uses hypothesis and employs a very rigid logic, but makes the one additional but all essential step of comparing deduction with experience and experiment. Any measure which will serve to impress the importance of this final step on those who will necessarily have a great and perhaps preponderating influence on the future legislation of the country, cannot fail to be of the utmost consequence, not merely to particular industries but to the nation at large.

One of the most successful industrial research associations so far founded is that established by the pottery trades. The outbreak of the war placed our pottery manufacturers in a very awkward position. For many years they had been content to be parasitic on German enterprise for the supply of certain essentials to their trade. In particular the seger cones used for controlling the temperatures of the kilns were all imported. If slack in the past, however, no other industry sooner bestirred itself to make good its needs. A short period of experiment by Dr. Mellor at Stoke sufficed to provide the cones, but matters did not stop there, and Dr. Mellor and Mr. Bernard Moore have, it is now announced, devised simple and practical means of making from British materials, the hard porcelains previously imported. This research has, it appears, been brought to a successful issue at a cost little more than one half as much as was anticipated, and the recipes for the body and glaze have been freely communicated to such firms as satisfied the committee that they are likely to make *bond fide* use of

the discovery. To further these investigations the Advisory Council are making a grant of 1,500*l.* for the erection of a new refractories research building at Stoke. The local authorities have provided the site, and the local manufacturers another 1,500*l.* towards the cost of the building. In the supply of refractories capable of withstanding extreme temperatures Germany had established a long lead over our own makers, who had quite failed to realise the importance of the scientific study of these essentials to our metallurgical industries. Great progress has, however, been made here during the last four years, both at the National Physical Laboratory and at other centres of research. The report now under review notes that the investigations carried out at Teddington have led to methods of using zirconia as a refractory, which have been patented, and are now being developed by Messrs Doulton.

The largest grant by the advisory council arranged for during the year, is a sum of 40,000*l.*, which is to be expended on researches connected with scientific instruments. As is well-known, Germany occupied a preponderating position in the trade in optical glass, and though extraordinary success has attended the effort made since 1914 to retrieve the position created by the failure of German supplies, much still remains to be done. The firms concerned, although their business has expanded enormously during the war, cannot feel certain as to what extent their trade will be maintained when the present abnormal conditions cease, and have not, therefore, seen their way to guarantee, for a period of years, subscriptions to a research association, though they are making a substantial, if temporary, contribution to the British Scientific Instrument Makers Research Association. The large contribution made by the advisory council is, no doubt, in part due to the consideration that the industry concerned is what is known as a "key" industry, the maintenance of which is of national importance, and cannot be dealt with solely from the standpoint of ordinary economics; where the advisability of a policy is judged solely by the immediate financial profits, and the possibility of a present sacrifice constituting the seed of a hundred-fold gain in the future, is totally ignored.

From the engineering standpoint the most interesting work now being financed by the council is that which the Board for Fuel Research have in hand in conjunction with the South Metropolitan Gas Company. Progress here is, however, necessarily slow, as building is only accomplished under difficulties. The plans for the Research station were complete nearly a twelvemonth back, and the work of erection is now in hand. Owing to the necessity of extensive piling, the foundations could not be begun before March last. Professor Thomas Gray, of the Royal Technical College, Glasgow, is to be in charge of the laboratories.

As responsible for the production of refrigerating machinery, engineers are also somewhat closely concerned in the work of the Food Investigation Board, to which the advisory council have allotted 5,000*l.* to meet the expenses of the first-half year's work. It is stated that as matters stand, thousands of tons of food are annually lost by decay before they can be marketed. The inquiry has been undertaken at the instance of the Cold Storage and Ice Association, who have arranged to supply free materials and cold storage accommodation. Experiments on the freezing of fish are now in progress at North Shields and also at Billingsgate Market. The value of heat-insulating materials is, in this connection, being investigated at the National Physical Laboratory.

Mention is made in the report of a number of other researches of engineering interest in progress, but not yet ripe for a useful report. Among these may be mentioned the inquiry into the strength of home-grown timber, the investigation into the properties of new building materials, and the scrutiny into the possibility of a supply of tungsten from Cornwall, where the first results have, it appears, been of a very encouraging character. The work of the committee which is making an investigation into industrial fatigue has been continued, and may well lead to a revolution in factory routine.

BRITISH ROADS.

That the conditions during the past four years have been exceptionally trying to our highways is a view very commonly expressed, and in certain cases no doubt the traffic has fully justified the term "extraordinary." This has been more particularly marked in the neighbourhood of camps and other military establishments. That this would be the case was early recognised, and it was agreed that additional costs to road authorities thus arising, should be assessed by the Road Board and met by grants from the national exchequer. In a recent address to the Institution of Municipal and County Engineers, Sir George Gibb has expressed a doubt whether, apart from these special cases and taking the country as a whole, the highway traffic has been in any way more severe than it would have been had its natural development not been checked by the restrictions due to the war. These restrictions have relieved the roads of much burdensome traffic, of a kind that was developing at a steadily accelerating pace for a considerable period before the war.

The above expression of opinion from such an authoritative source is interesting, but at first sight a little surprising, in face of the fact that rail traffic has, during the same period of time, far transcended all previous records. No doubt some of this increased traffic on the railways has arisen from the circumstance that the Government, having taken over the railways, pay neither freights nor fares for goods or *personnel* transported on national account. Certain restraints on departmental activities are thus removed and there have been accordingly at least occasional rumours of tons of shells being despatched hundreds of miles to suit the convenience of an inspector. Incidental instances of such transfers of a mountain to mahomet, can at most, however, have been responsible for but a small fraction in the additional traffic handled by our railways, and it would have been natural to expect that this increase would have been accompanied by a corresponding growth in road transportation. That this growth has not on the whole exceeded what might have been expected from the normal development of highway traffic is noteworthy.

Maintenance has, of course, been difficult. Some 60 per cent. of the staffs formerly employed in this service have been diverted to military necessities of one kind or another, and in view of this it is gratifying and encouraging to find that many very heavily-travelled roads are still in excellent condition. Nevertheless, vast sums will have to be found in the future for road improvements, if proper provision is to be made for the national requirements. In the aggregate the expenditure will be large, but an analysis of recent road costs at Maidstone made by Mr. A. Dryland at a recent meeting of the Institution of Municipal and County engineers seems to show that with well constructed roads carrying heavy traffic the cost of maintenance is probably the smallest of all the components involved in the total cost of road transport.

The total cost of maintaining tar macadam at Maidstone during the past seven years has, it appears, averaged 10½*d.* per square yard, which is, Mr. Dryland stated, equivalent to a charge of 0·0174*d.* per ton-mile of transportation.

Nevertheless, whether this estimate be or be not too optimistic the aggregate costs are likely to continue to increase, and as matters stand the burden is often very inequitably distributed. The extended use of the motor has greatly increased the amount of through traffic on the roads. By this through traffic, intermediate areas benefit little or nothing, yet on them falls almost the whole of the increased cost of maintenance. Even as long ago as 1882, although our highways were almost deserted, it was recognised that rural districts had a claim for assistance from the national exchequer. The amount then granted was about 500,000*l.*, which was approximately one-sixth the total annual cost of the country roads. In 1915 these annual road costs had increased to about 10,000,000*l.*, of which 1,000,000*l.* was derived from exchequer grants. In this latter year, however, the highway authorities received additional assistance in the form of loans and grants from the Road Board. Up to March 31 last the grants thus arranged for aggregated 5,099,512*l.* As is well known, the main source of the Road Boards' revenue has been diverted to meet what are considered to be more pressing national needs, and though it is to be hoped that it will ultimately prove practicable to replace the Board in its old position, this hope may be long deferred. It has, moreover, to be borne in mind that a very important Road Bill was under consideration in Parliament when the war broke out. The proposal was that the Road Board should classify the highways of the kingdom into three groups according to their importance as units in a complete system of road communication. It was provided that the State should pay one-half the cost of maintaining first-class roads and one-quarter the maintenance cost of the second-class roads, whilst the local authorities would themselves be wholly responsible for the costs of the third-class roads, which would be those of purely local interest. Under this scheme the actual work of maintenance would be carried out by the local authorities, thus preserving the enterprise and initiative which led the delegates to the International Roads Congress at its London meeting to declare that Great Britain had been more successful than any other country in meeting the new conditions introduced by mechanically-propelled vehicles. Of course, such a scheme will not secure the uniformity so much desiderated by a certain type of mind, but uniformity is as incompatible with progress as equality is with liberty.

The influence of the Road Board would, of course, ensure a certain amount of standardisation and would help each district to benefit by the experience and experiments of even remote areas. The best results will always, however, be dependent on the ability of the individual surveyor, and in all English-speaking countries local authorities seem to be most reluctant to admit this. Mr. Waddell, the well-known American bridge engineer, has instanced a case in which a lawyer was appointed to the post of county engineer on the plea that an aptitude for politics was more important than technical ability. In Canada we note complaints have recently been made as to the absurdly inadequate salaries attached to municipal and national engineering posts, with the result that the really good men apply only in the hope of gaining experience which they can transfer to a more profitable market later on. Sir George Gibb recognises the same difficulties here, and has suggested to the Departmental Committee on Local Taxation that some part of any further grants made to local authorities from national sources should be earmarked as a contribution to the cost of the salaries of county surveyors and their staffs.

LIGHTNING ARRESTERS AND THE OXIDE-FILM ARRESTER.

To the electrical engineer the term "lightning arresters" signifies in general any device intended to provide a direct discharge path to earth for sudden rises and surges in potential, such as lightning, switching operations and other causes may call forth, for the protection of apparatus which the high potentials would endanger, and not merely lightning arresters in the strict sense, which were historically the first in the field, of course. As long as electric circuits and lines carried only low-potential telegraph currents of small intensity, a simple minute spark gap to ground, readily crossed by the lightning discharge, afforded the required protection. When power-distribution lines were put up, the simple spark gap was no longer sufficient, not even on telegraph and telephone lines into which power currents might accidentally find their way. For when the high-potential discharge had once broken down the insulation of the gap, the power current might follow that path, a short circuit would be established and the safety devices themselves be endangered. It was hence necessary to provide for means of re-opening the gap circuit at once again. The horn-type arrester answered that purpose to a certain extent. The horns, two stout wires, bent in the same vertical plane, approach one another closely at the lowest point and recede from one another higher up; any arc formed by the discharge is driven up the horns by the dynamic reaction and the heat generated, until the arc snaps off. Though this self-interruption of the arc generally occurs

within a small fraction of a second, it is not sufficiently rapid for the purpose; magnetic blow-out devices were hence combined with arresters of the horn type and similar types, and this combination is still used on direct-current railway circuits.

For alternating circuits of small electrostatic capacity the multiple-gap arrester came into use. In this type several metallic cylinders are mounted in an insulating frame parallel to one another, electrically in series or partly in shunt, so that the discharge has to cross a number of gaps in succession, several dozens sometimes. The sum of the component spark-widths is greater than that of an equivalent simple gap; in other words, the multiple gap operates at a lower voltage than a single gap of equal width. The lightning discharge closes the circuit to earth, but the power arc following the discharge is extinguished at the end of the half-wave of the alternating current, as the non-arcing character of the gap does not permit the reverse current of the next half-wave to start. The multiple gap arrester hence short circuits for a part of half a wave; it is only suited for alternating current, and the cylinder should be made of "non-arcing" metal. About the nature of these metals very little has been published. When A. J. Wurts described these arresters first in 1892, he briefly recommended elements of two groups, the group of magnesium, cadmium, zinc, mercury, and the group of antimony, bismuth, phosphorus, arsenic; he had obtained the best results with mercury (in the form of amalgamated copper), cadmium and bismuth. Others found cylinders of aluminium and of zinc alloys, which were apt to fuse together, little superior to brass; various "non-arcing" metals were and are on the market.

When circuits of considerable electrostatic capacity, such as high-voltage transmissions or underground cable systems, and lower-voltage circuits inductively connected with the former, came into use, the multiple gap failed frequently, because the high-frequency oscillations between capacity and inductance, set up by lightning or switching operations, cannot be dissipated within half a wave period. In these cases a device is wanted which does not short-circuit the power current for even a fraction of a half wave, but which merely discharges the over voltage, the oscillation being small in energy. The only arrester of this type so far used is the electrolytic aluminium cell, a development of the Wehnelt cell, which has done excellent service during the last ten years. The arrester consists of a number of conical cells stacked into one another; each cell is "formed" in the usual fashion, by sending alternating currents through the cell, so that each electrode becomes covered with a very thin, but electrically strong film of aluminium hydrate which stops the impressed voltage up to 250 volts or 300 volts; any higher voltage pierces the film in a fine hole, which closes up again immediately. By arranging several cells in series, high voltages are stopped, and the only drawbacks of the electrolytic arrester are the inconvenience of having daily to attend to an electrolyte which has to be renewed, and that the arrester cannot be tested without being taken to pieces.

The newest type of arrester, the oxide-film arrester, has several features in common with the electrolytic device, but the material is a solid peroxide of lead, the construction is simple, and the arrester requires very little attendance. The novelty is described by Mr. C. P. Steinmetz, who attributes the invention chiefly to Messrs. E. E. F. Creighton, Crosby Field and N. A. Lougee, and by the patentee, Mr. Crosby Field, in the June issue, 1918, of the Journal of the American Institute of Electrical Engineers. A considerable number of the oxide film arresters for voltages from 110 up to 33,000 have been in use for three years. An arrester cell to stop 300 volts consists of a flat cake of peroxide, 6 in. in diameter, $\frac{1}{2}$ in. thick, within a casing of sheet steel formed by two discs—the electrodes—which are spun on a ring of porcelain; the ring forms the rim of the cell. As in other multiple arresters several such cells are piled upon one another in series. The principle underlying the new arrester is that lead peroxide PbO_2 is normally a fair conductor, having a resistance of about 1 ohm per inch cube, but becomes an insulator when hot. When heated to 150 deg. C., the PbO_2 loses oxygen and turns into red lead or minium, Pb_3O_4 which has a resistance of 24,000,000 ohms per inch cube; at still higher temperatures the sesquioxide Pb_2O_3, and finally the oxide or litharge PbO are produced, which are practically insulators. The oxides of bismuth and of some other metals show similar peculiarities. The peroxide cell as described would allow the ordinary current to pass. In order to prevent this initial flow, the steel discs are painted or electrolytically coated on the inside with litharge which forms a thin insulating film of oxide, or simply coated with alumina, a varnish, some paint, shellac, glass, water glass, cloth, &c. The discs may also be sprinkled with peroxide and then heated. As soon as the volts rise abnormally, this insulating film breaks down, and the discharge to earth pierces also the peroxide, puncturing it in one or several very fine holes, about 0·05 mm. in diameter. The current rush following this discharge locally heats the fine channels and turns the peroxide particles along the paths into insulating litharge, thus sealing the paths. As thousands of discharges pass, the peroxide becomes plugged with irregular threads of litharge, and the dark brown surface turns more and more yellow with irregular oxide specks. The melting oxide also penetrates into the holes in the oxide film or paint and seals these holes. The critical voltage under which the arresters will operate depends upon the thickness of this film and may be raised from 300 volts to 500 volts by increasing that thickness. With the repeated operations of the arrester, however, the film thickens more and more, and that circumstance limits its useful life.

The oscillograph curves taken by Steinmetz, Creighton and others, demonstrate that the oxide-film arrester operates more rapidly, and that the ordinary leakage current is smaller than with the electrolytic aluminium cell. Neither type, nor any other type of arrester is in itself perfect and complete, however. They all require some additional part, resistances, choking coils, or spark gaps, and the study of the functions of these main and auxiliary devices has necessitated a great deal of arduous research work. Most of this work has undoubtedly been done in America, where violent atmospheric disturbances are more frequent and high-voltage power transmission was adopted earlier than in the United Kingdom. But the Continental workers, notably in Switzerland and Italy, have also contributed to the elucidation of these problems, and the investigations are not so exclusively American as it might appear from the summary given by Dr. Steinmetz, though nobody will question the high credit due to the men mentioned, and to F. W. Peek, Rushmore and Dubois, H. C. Wirt and others. Laboratory tests of these apparatus do not lead very far; observations have to be taken under service conditions. The ordinary horn gap is joined to the line by a resistance. But it is also shunted by a sphere-gap of good proportions, because a very sudden high voltage with a steep wave front may pass by a horn-gap, but flash over elsewhere. The sphere-gap is more instantaneous than the needle-gap, which was formerly in favour. There is a time lag in all the gaps, but it is greater with needle-gaps, and the rupture energy is also greater in their case than with sphere-gaps. Using spheres of 25 cm. diameter, Peek found a needle gap spacing of 15 cm. equivalent to a sphere-gap of 3·5 cm. The spark-over does not, with continuously applied voltages, take place immediately after the break-down pressure is reached; the excess of volts required to cause breakdown is the greater, the greater the rate of application, and further factors of importance are the nature of the dielectric, the shape and spacing of the electrodes and the initial ionisation of the air in the gap. Trains of electric waves may further set up internal resonance surgings which locally endanger the apparatus. With high frequency currents the wet or dry state of the atmosphere does not influence the discharge voltage of the gap; but with low-frequency currents the rain lowers the voltage, and the sphere-gap is therefore protected. To keep the rain off the oxide-film cells, the sets of cells, arranged in a column, which is surmounted by the horn-arrester and sphere-gap, are surrounded by a petticoat of iron. To guard off high-frequency disturbances of moderate tension the arrester is further combined with a capacity-discharge path permanently connected from the circuit to the ground. This path, Dr. Steinmetz considers should be without resistance and contain a moderate series resistance to dissipate high-frequency energy and stop cumulative oscillations in their beginning. His perfect arrester of the aluminium-cell or oxide-film type should have no spark-gap, but should permanently be shunted across the circuit. We should add that Dr. Steinmetz spoke of electrodes of sherardised iron as preferable to the brass electrode they had first used; Mr. Creighton only mentioned steel discs.

THE DOPPLER PRINCIPLE.

In a treatise on the "Coloured Light of Double Stars," published in 1842, Christian Doppler, professor of mathematics at the Technical School of Prague, enunciated the principle, that when a source of sound (or light) approached the ear (or eye), the observer would receive more waves per second than with the source at rest, and would hence have the sensation of a higher note (or of more bluish light of higher frequency). With a receding source the tone would be deeper and the light more reddish, of lower frequency. Acoustically the principle was soon verified both by placing trumpeters blowing their instruments in a moving train with the observer on the station platform, and by putting the observer in the train and the trumpeters on the platform. As regards light the enormous velocity of light seemed to exclude the possibility of an experimental verification. Studying the spectra of stars early in the 'sixties Sir William Huggins noticed, however, that the F line of Sirius was slightly displaced to the red when compared with the same line in a hydrogen tube, and he concluded that Sirius was moving away from us.

The Doppler principle has since been applied apparently with triumphant success in many ways by astronomers and in recent years also by Stark in the study of canal rays. Such applications do not constitute any verification, however. An approximate experimental confirmation of the principle for light was first given by Belopolsky in 1901, and later, in 1907, by Galitzin and Wilip. In 1914, Ch. Fabry and H. Buisson (*Comptes Rendus*, May 25, 1914) were able to make exact measurements. Their apparatus consisted of a horizontal disc of white paper, 16 cm. in diameter, which was rotated about its vertical axis at 200 revolutions per second so as to obtain a circumferential speed of 100 m. per second. Above the disc they mounted a quartz-mercury lamp diametrically to the disc in such a way that the points A and B on the edges of the disc, being the ends of a diameter representing the projection of the lamp, were receiving light travelling at right angles to their motions. Looking very obliquely at the disc the observer saw the disc as a long elipse, with the point A as a source of light approaching him and B receding from him at high speed. With the aid of their delicate interferometer Fabry and Buisson found that the measured displacement of the interference rings was in agreement with the Doppler principle.

Last year Q. Majorana approached the interesting problem from a different point of view by devising an apparatus which demonstrated the constancy of the velocity of light reflected from a rotating mirror. If the velocity c of light of frequency n be not changed by being reflected from the mirror, having a velocity component v in the direction of the reflected ray, then (by Doppler's principle) the frequency n should change into $n_1 = n(1 + \beta)$, where $\beta = v/c$, while the wavelength λ should change into $\lambda_1 = \lambda(1 - \beta)$. If, on the other hand, the velocity of light c be changed by the rotation of the mirror (as some physicists assert), then the new n should still have the value just given, but λ_1 should remain λ (unchanged). Majorana (*Comptes Rendus*, October 1, 1917) mounted on the circumference of a rotating wheel of 38 cm. diameter ten suitably inclined mirrors in such a way that the image from the last mirror (only four were used as a rule) travelled at 450 m.

per second; observations with a Michelson interferometer showed a displacement of 0·7 or 0·8 of a fringe, when the displacement should have amounted to 0·71 fringe on the former assumption of the constancy of *c*.

By an elaborate similar device Majorana (*ibid.*, July 8, 1918) further demonstrated the constancy of the velocity of light emitted by a moving source. In this last apparatus two small vacuum tubes of peculiar type, containing some mercury and each provided with three electrodes, are fixed to the ends of a diameter, 2 m. long, of a rotating wheel, and receive current by brushes; two of the electrodes may be bared of the mercury in the tube by the centrifugal force. The interferometer observations agreed with the theory within 5 per cent.; the discrepancy is ascribed to experimental errors, but it might possibly be due to faulty theory. The principle of relativity is said to be confirmed by the experiments.

NOTES.

Lifting Gear at the Hog Island Shipyard.

In an article recently published in *The Engineering News Record*, particulars are given of the lifting arrangements adopted at the great Hog Island shipyard which has 50 building slips. The ships to be built are of the "fabricated" type, and the plant used for erecting the steel is much the same as is employed in the States for erecting structural steel work. Whilst at other yards overhead travelling cranes have proved very satisfactory, derricks were adopted at Hog Island. One great advantage was that whilst special shipbuilding cranes of the pattern hitherto used would have had to be built as special orders involving months of delay, the derricks could be obtained quickly and in large numbers. These derricks are mounted on fixed towers from 53 ft. to 66 ft. high. The derricking boom is 80 ft. long and the vertical strut 43 ft. 6 in. high. There are eight booms per ship over the ways plus an additional derrick near the head of each way. The ship under construction is offset from the centre line between the two rows of towers thus providing room for a railway track between the hull and the towers on the other side. No part of a ship under construction is served by less than two hooks, whilst in some positions three or four hooks are available. Generally the parts to be lifted as received from the bridge yards weigh less than 2 tons, but the derricks actually provided have a lifting capacity of 5 tons each. Electric power is supplied for operating the derricks, alternate current motors being used. The current is transmitted at a high voltage from Philadelphia and stepped down to 440 volts for the yard services. All the material arrives by rail and it is intended as far as practicable to run it direct to the ways without entering it first to a storage yard.

The Temperature of Luminous Flames.

The temperature of luminous flames can be determined by two methods. It can either be deduced from the radiation laws, or it can be determined by introducing bodies into the flame and measuring the temperature which the bodies assume. Both methods are open to objections. In the latter method the objections are that heat is lost by the body through conduction and radiation, and that the body itself cools the flame into which it is introduced. To overcome the first objection, heat is imparted—generally by the electric current—to the body while in the flame, at the rate at which the heat is lost; the point is then to determine the amount of heat required to establish stable conditions. This is possible in the case of the non-luminous flame of a Bunsen burner, but not when the flame is self-luminous because it contains glowing particles of carbon or of some other substance. Dr. H. Senftleben and Miss E. Benedicks, of Breslau, have, however, found a criterion which makes the electric-heat compensation method applicable for flames containing incandescent carbon particles. They argue that the carbon will only be deposited on the body introduced (mostly a wire), when the wire is colder than the flame; if the flame and wire be at the same temperature, there should be no deposition of soot—a questionable assertion—but the soot should at once appear, when the wire temperature falls below the flame temperature. Thus they regulate the temperature of the platinum (or gold) wire they use for their experiments until the soot deposition ceases; at that moment they determine the "black" temperature of the wire by means of a Holborn-Kurlbaum pyrometer, and find the "true" temperature of the wire from the known reflecting power of platinum at different temperatures. Applying the method first to the Hefner standard candle (amyl acetate lamp), they found a temperature of 1,705 deg. C. absolute, correct probably within 20 deg. In this determination the influence of the radiating part of the flame between the instrument and the wire was, however, disregarded; there is on the other hand an absorption of the radiation from the wire by this portion of the flame. The two factors would oppose one another, and Senftleben considers that the influence is small, but that in the case of the Hefner candle the true temperature should probably be reduced by 1 per cent., *i.e.*, to 1,690 deg. C. absolute. To study the further disturbing cooling influence of the introduction of the wire, they experimented with wires ranging in diameter from 0·2 mm. up to 1 mm.; they observed a slight cooling influence only with the thick wires. Platinum and carbon are known to combine, however, at high temperature; any direct influence of this combination was not observed, but it was found that, after using the same wire several times, the soot-deposition became less distinct. Further to investigate this point they took gold wires instead of platinum wires, gold not being liable to carbide formation; in these experiments ordinary oil flames were also used, more or less sooty; in these sooty flames the temperature went down to 1,150 deg., but the determination of the temperature of the Hefner candle gave the former value 1,690 deg. C. absolute. The influence of carbide formation likewise would therefore appear to be small. This value is also in fair agreement with other determinations previously made by Kurlbaum (1,711 deg.), Ladenburg (1,688 deg. and 1,715 deg. by different methods), Becher (1,680 deg.) for the temperature of the Hefner flame, and may thus be accepted. It should be noted that the temperatures stated are absolute; on the ordinary centigrade scale the melting-point of platinum is assumed to be about 1,783 deg.

The Central Europe Movement.

Although a decided opinion has been expressed in influential German quarters to the effect that there was rather too much "Mitteleuropa" propaganda and talk, the movement has been endowed with a new important factor in the shape of the German Industrial and Commercial Council for Central Europe, with none other than Herr Generaldirector Ballin at its head, and a number of other influential gentlemen on its board. On its formation it was stated that a Central European industrial and commercial committee must be created, which may become an important international factor. The programme states that the Council for Central Europe not only has to work up commercial relations with Austria-Hungary, Poland, Ukraine and other adjoining Eastern countries and peoples, but has also and more particularly to investigate isolated commercial and industrial questions of special importance for the German industry. As instances mention is made of the vast amount of work which will have to be carried out in the new States of Western and Southern Russia and the reconstruction of the huge district devastated by the war, in which, it is contended, "German industry must become primarily interested." This must be duly secured for Germany by agreements so that the competition from America and other Entente countries, aided by cheaper raw materials, can be frustrated. In this connection it may be stated that among 120 towns in Poland only eight at present possess waterworks, gas or electric lighting. That it is of great interest to the German industry to secure contracts for the public works in question goes without saying. The example from Poland is only one amongst a hundred; conditions in the former Russian Baltic provinces, or as the Germans now call them, "Baltikum," and in Lithuania are more backward still. The war has wrought within the last two areas tremendous havoc, and these areas lack entirely all necessary home production, even saw mills, brickworks, &c. The situation, it is said, can only be improved by German aid, unless indeed the enemy nations should interfere to the detriment of Germany. These districts are also of special importance on account of their wealth of raw materials. Special importance also attaches to establishing a closer connection, through the intermediary of the Government of Ukraine, between the South Russian ore deposits and the German iron and steel works. The new Council for Central Europe must develop into a purchasing and distributing centre for the German industry. Another important task for the council is the establishment of a Central European railway tariff system to facilitate the export of Germany's products to Austria-Hungary and Poland, to facilitate also transit to the Balkan States and Ukraine, and avert an undesirable traffic policy on the part of Austria-Hungary and Poland. This involves the extension and completion of railways and waterways. The organisation for the development of German exports to the East and South-East will, however, in no way clash with the overseas problems which await Germany after the war. Before the war Germany's exports to the East and the South-East stood at 32 per cent., against 68 per cent. of her total exports, but the changes worked by the war as regards the East may reverse this proportion, at least for some time to come. This growth of the East, however, means much to her, since her former industrial and commercial strength will have to be regained there before Germany can embrace the whole world. Nevertheless, and on the basis of activities towards the East and South-East, efforts must at once be made by German enterprise, says the council, to build up international relations for improving the German exchange. The means of attaining this end is a peaceful re-conquering of the world. Surprise has been voiced at the new Central European Council having no apparent connection with the large German industrial unions.

LITERATURE.

A Handbook of Briquetting. By Professor G. Franke, of the Kgl. Berg-akademie, Berlin. Translated by Fred. C. A. H. Lantsberry, M.Sc., Head of the Birmingham Small Arms Company's Laboratory. Vol. II. *Briquetting of Ores, Metallurgical Products, Metal Swarf, and Similar Materials, including Agglomeration.* London: C. Griffin and Co. [Price 15s. net.]

This treatise is a translation of the second volume of a well-known German work, wherein is discussed in great detail the subject of briquetting of ores and fuel materials. A notice of the portion dealing with the briquetting of coals and lignites has already appeared in these columns, and we may say that the thoroughness and good qualities that characterised the previous instalment are repeated in this continuation. It may not, however, exhibit the latest applications of German ingenuity in this particular industry. The date of the German issue is not given, but there is some internal evidence to suggest that the book appeared before the war, and there are few references to current literature subsequent to 1909. The expression "up to the present time," which is repeatedly used, may be misleading, and we strongly suspect that the exigencies of the war have taught the thrifty German to utilise waste products with even more scrupulous care than is here indicated, and that his technical skill has evolved machinery still better adapted than that described.

The object the author has in view is distinctly economical and eminently praiseworthy, for he urges the utilisation and recovery of what is valuable in waste materials. His lessons are worthy of study and his methods possibly of imitation. In this country, we have not experienced that scarcity of raw material which makes restraint a necessity, and frugality a merit. Our national character is inclined to display a tendency to extravagance that is little to our credit. Our conservative habits confirm us in the wasteful courses that we have inherited from days of greater plenty and less competition, and induce us to look somewhat scornfully at the devices Professor Franke tenders for our instruction. In the past, millions of tons of small coal, unsuited to coke-making, have been

treated as waste and neglected because round coal was easily procurable and more readily saleable; it may be feared that the same reckless disregard of metallic ores prevails when circumstances make their collection troublesome or little remunerative. Wherever fine material arises from mining operations and the increasingly destructive action of powerful explosives tends to aggravate such accumulations, where disintegration follows prolonged storage in the open, or where breakage and attrition are the consequences of carriage, waste of valuable material results, and the loss is regarded as inevitable. The author calls special attention to the waste of hematite ore, to the loss of soft iron ore in the Mesabi district, and the scattering of the powdery manganese ores of the Caucasus, but in other industries, as in zinc smelting, in the production of aluminium, wherever in fact the necessity for heedfulness does not press, the less valuable or less conveniently handled product will be passed over in favour of the more easily worked material. Professor Franke goes, however, beyond the utilisation of crude ores, wherein lies a large field for the exercise of economy. He perceives a neglected source of national wealth in the by-products of smelting furnaces, in the flue dust from iron blast furnaces and in many metalliferous processes as now conducted. "Roll cinder" from iron and steel rolling mills, iron-rich residues obtained during the grinding of basic slag, and many similar operations furnish materials now given to waste, and form an actual burden to the manufacturer, but this same waste it is urged, can be made to yield a handsome profit, if submitted to a judicious process of briquetting and subsequent metallurgical treatment.

Following the author's figures, there can be little doubt of the quantity of material available. He urges that some 1,500,000 tons of flue dust alone might be collected from the many plants of the German Empire, and on the assumption that the iron content is 35 per cent., evidently 525,000 tons of pig-iron are waiting to be collected. At the prevailing prices, presumably those before the war, the briquetted material is worth 13·60 marks per ton, whence it is easy to see that the flue dust going to waste annually is practically worth a million sterling. Later, we learn that the cost of briquetting, that is the necessary preparation for subsequent treatment in the furnace, in a single press plant with a yearly output of 50,000 tons, only amounts to 1·80 marks per ton, and this moderate charge includes interest and depreciation. With such figures there is evidently a case for examination. A plant that has an annual output of 50,000 tons has passed beyond the experimental stage, and may claim to be exploiting a profitable industry. Beyond the pecuniary return derivable from the agglomeration of flue dust and the waste products of iron smelting, other advantages are claimed for the process. Among these are to be reckoned the diminishing of detrimental impurities, especially sulphur, and the reduction of the costs of production of the crude iron. We have little information how far these rose-coloured projects are realised in practice, or what special and local difficulties may have to be encountered before these potential sources of wealth are handled, but in any case the increased need and greater consumption of ores, the heavier charges for freightage, the growing scarcity of rich ore, and the necessity of concentrating poor ones by some process of agglomeration, all point to the desirability of reducing waste and of turning to the fullest account the iron content of the ore by every means at command.

Success will depend in great measure on the quality of the briquette produced, and herein the experience and advice of the author should be valuable. The essential qualities to be secured in the finished briquette are sufficient rigidity or cohesion to withstand open storage without injury from weather, and at the same time the preservation of such a porous character, that in the process of smelting, gases may penetrate the interior. The briquette must be capable of resisting the action of steam heated to 150 deg. C., and the material must hold together till reduction is practically complete and fusion begun; that is up to a temperature of 1,000 deg. C. Briquetting will usually necessitate the use of some binding material, but this must not contain any appreciable amount of sulphur or of alkalies calculated to injure the iron to be smelted or the lining of the furnace. Lastly it goes without saying, that the selling price of the agglomerate must not be higher than lump ores of the same content. So important has the industry become in Germany, that the establishment of a testing laboratory under State tutelage has been ventilated, but "up to the present" no active steps have been taken.

To explain how these objects have been achieved or attempted is the task the author has undertaken The order adopted in describing the several operations does not seem the most logical. Since the material, whatever its source, needs some preliminary treatment, this should be considered before the formation of the briquette, a later stage of the general process. This necessary preparation will depend upon the nature, composition, size of particles, properties, moisture content, &c., qualities that will often determine the choice of a binding agent. If the material consists of hard stony lumps, or of ore of poor quality intended for concentration, pulverising is necessary, to be followed by sieving. Concentration will be promoted either by gravity, separating the particles according to weight, or magnetic separators can be used to free the finer particles of iron ore from foreign gangue, the strength of the magnetic field being arranged according to the nature of the specimen and the amount of water present. Weak magnetic fields are also well adapted for collecting metallic iron in the form of roll cinder, filings, drillings, swarf from moulding sand, &c. Such refuse may need moistening, but this is easily managed; on the other hand, lixiviated burnt pyrites and slimy ores may contain too much moisture and require drying, but as the materials are non-combustible, artificial drying can be carried on by means of blast furnace gases mixed with air. Several appliances are on the market for this purpose, and are used in similar operations. Mixing of the refuse is not a process peculiar to ore briquetting, and the methods in general use by means of rotating distribution tables, and mixing worms, are applicable here.

The next operation consists in giving to the suitably-graded and prepared mixture the necessary cohesive power. If, owing to the presence of clays or other adhesives, briquetting can be effected without a binder, or if a sintering process can be adopted, the result may be more satisfactory since there is no impoverishment of the material or fear of introduction of impurities. In all sintering operations, however, it is important that the sintering temperature be kept well below that of fusion. The partial melting of the ore particles, or the formation of a fused crust on the briquettes, destroying their porous character, is fatal to successful manufacture. Moreover, a high fuel consumption is inevitable in sintering, and the process is feasible only where an ample supply of fine coal or waste coke exists. If a bond is used, the process is best carried on where clayey iron ores or purple ores containing sodium sulphate are available. Non-ferruginous clays are not recommended, since a large quantity has to be used to ensure cohesion after calcination, and the subsequent treatment always necessary to remove the water of hydration. When other inorganic binders are used, as lime, or cement, the briquette is liable to disintegrate in the furnace and cause trouble. Some organic materials, though usually expensive, have been tried as binders with good results, and attempts have been made to effect a saving on the necessary fuel by utilising their heat of combustion. Of these organic binders, the most interesting and the one that is gaining most in popularity, is "cell pitch," a product derived from the waste liquors of cellulose factories. The water contains about 10 per cent of solid material, recoverable after evaporation, and may be used either in lumps or in the form of a powder. The product possesses greater adhesive power than coal tar pitch, and its cost is about the same, 40 marks per ton. It burns without smoke, cokes before combustion sets in, and briquettes made with it stand up well in the fire and do not crush under the load. As the supply of cellulose waste is practically inexhaustible, a promising future apparently awaits its further development, though the calorific value is much less than that of coal-tar pitch.

Briquetting material will generally have to be submitted to considerable pressure to obtain a rigid block, though occasionally circumstances favour simple hand moulding. Burnt pyrites are treated in this way in some parts of Scotland, the sodium sulphate left in the residue acting as sufficient bond. As a rule, drop-stamp presses and revolving table presses capable of exerting very high pressures are needed. Various forms of press are very fully described, and among these, full details and a favourable report are given of the "Emperor" press built by Messrs. Sutcliffe, Speakman and Co., of Leigh, Lancashire. This is, we think, the only mention of English machinery, and in a future German edition, we imagine this notice will be deleted. These Sutcliffe presses have been used at Helsingborg to replace an obsolete form of drop press, and we hope we may give this unsolicited testimonial from one who we feel sure would be now an unwilling witness:—

Pressure System.	Output per Hour.		Power Consumption.	Working Staff.	
	Number of Briquettes	Weight of Briquettes		Charging	Unloading.
		kg.	h.p.		
Sutcliffe pressure ..	1440	5760	4–5	1	4
Drop pressure ..	600	2100	3–4	1	1

Simple pressure is usually not sufficient to give the necessary rigidity and consistency. Exposure to the air, with consequent absorption of oxygen and carbon dioxide is found to have a good effect. In other cases, the pressed block is submitted to superheated steam (165 deg. to 179 deg. C.) for some hours with the view of forming a lime silicate. But waste gases of 500 deg. C. are often used to encourage the absorption of CO_2, and in the case of briquettes made from argillaceous ores, actual burning in kilns is necessary to drive off the water of hydration.

In his last section the author describes some complete briquetting plants and these chapters are not the least instructive portions of the book. They picture the whole operation with great completeness, and show how mechanical ingenuity has improved and cheapened the process. They indicate the growing importance of the industry and the stability of its future, while emphasising the need for the utmost utilisation of waste products, or increasing the amount of available raw material. We do not doubt but that the last few years, when import into Germany has been much restricted, increasing attention has been paid to the application of a valuable economic scheme, but any general improvement in the processes is not to be anticipated. The Rönay plan characterised by the absence of binding material and the employment of very high pressures amounting in some instances to 2,000 atmospheres, will furnish a main type, around which improvements in detail will centre, while the Grondal system, of proved value in concentrating and enriching poor ores, will point to another direction in which extension may be anticipated. Other industries will suggest the adaptation of machinery that has been found useful or economical, and there are signs that the revolving-tube furnace, as employed in the manufacture of cement, will take a foremost place in the calcining operations. Indeed we are candidly, but perhaps prematurely informed, that one famous firm, specialising in these furnaces, proposes to install them in a new plant to be erected in England for the agglomeration of ores.

The Design of Toothed Gear. By CLAUDE W. HILL. London: Charles Griffin and Co., Limited. [Price 3s. 6d. net.]

THIS book of 60 pages, with 17 illustrations, is not a treatise on the general subject of toothed gearing, but a monograph which deals only with some particular aspects of the design. Much of it relates to the Brown and Sharpe construction, and is, therefore, familiar, and most of the formulae have been already given in the author's book on "Electric Crane

Construction," where the subject is discussed at greater length.

Only the elementary principles of the involute form of tooth are considered, with mathematical demonstrations. Since the major portion of the book consists of re-statements of well-known facts and principles, no criticism is needed. The subjects treated are the design and the proportions of involute teeth of the standard form, the angle of incidence or obliquity, the positions of the base circles, the clearances, the amount of sliding of teeth in contact, and the problem of undercut in pinions of less than 30 teeth. These matters are all dealt with very clearly.

Mr. Hill has some remarks about the wear of teeth, which results when the load is taken on one tooth only, which wear, with the consequent deformation, does not occur when it is borne by two teeth throughout the entire arc of action. He includes also the case of gears in which the load changes from one tooth on to two teeth for a certain period. Only when two teeth are always in contact are the pressure and the wear uniform, and ideal conditions realised. But, unfortunately, pinions of less than 30 teeth are unavoidable. They are a majority in crane work, and in boxes of gears, and are a source of noise, as well as a cause of wear. Years ago, they were frequently cut in steel, or in phosphor bronze, in which case they could not be reinforced with shroudings. Now raw hide, and paper, are in some favour. But the practice of the automobile builders affords the best solution. By using a special steel, heat treated, and case hardened, and then ground, the life of small pinions is greatly prolonged. Even when two teeth are believed to be in constant mesh, it is doubtful if they are, in fact, after wear of teeth and shafts has occurred. The Wilfred Lewis formula, so largely used, assumes that the whole of the load is taken on one tooth. The old practice of inserting an odd or hunting tooth, is recommended, and the results in diminution of wear demonstrated.

In estimating the strength of teeth, the author treats them as cantilevers of rectangular section, and from this basis obtains a general formula for the strength of gears having different numbers of teeth, in which the load comes on one, or on more than one, tooth. As the general formula relates to loading at slow speeds, the value of the safe stress per inch of the material has to be lowered for increased speeds, or a higher factor of safety has to be used. Curves for these are plotted, derived from observations of a number of gears working satisfactorily. The book concludes with formulæ for the strength of shafts, and with some typical examples of designing spur and bevel gears.

Perusing this book, one is reminded of a radical change that has occurred in the design of gear teeth during very recent years. The cycloidal or double-curve form is not mentioned by Mr. Hill. Yet, until latterly, no other shape was deemed suitable for crane service, or, indeed, for general engineering constructions. Its abandonment is a result, first, of the growth of the practice of cutting gear teeth, and, second, of the vast extension of generating methods. The single curve involute presents a simple problem by comparison with that of the cycloidal. Its general employment has also been favourable to the shortening of teeth, where the stub tooth is the last record.

BOOKS RECEIVED.

The Chemical Analysis of Iron; A Complete Account of all the best-known Methods for the Analysis of Iron, Steel, Pig-Iron, Alloy Metals, Iron Ore, Limestone, Slag, Clay, Sand, Coal and Coke. By Andrew Alexander Blair. Eighth edition. Philadelphia and London: J B Lippincott Company. [Price 21*s.* net.]

Wireless Telegraphy and Telephony. By W. H. Eccles, D.Sc., A.R.C.S., M.I.E.E. Second Edition, revised and enlarged. London: Benn Brothers, Limited, "The Electrician" Offices. [Price, 22*s.* net.]

The Mercantile Year Book and Directory of Exporters, 1918. Edited by Walter Lindley-Jones. London: Lindley Jones and Brother. [Price, 15*s.*]

U.S. Bureau of Mines. Metal Mine Accidents in the United States during the Calendar year 1916. Compiled by Albert H. Fay. Washington: Government Printing Office. [Price 10 cents.]

U.S. Bureau of Mines. Quarry Accidents in the United States during the Calendar Year 1916. Compiled by Albert H. Fay. Washington: Government Printing Office. [Price 10 cents.]

INDUSTRIAL NOTES.

With a view to the better co-ordination of the functions of the several Government Departments concerned in the regulation and supply of labour, the Ministry of National Service, the Ministry of Labour, and the Ministry of Munitions have agreed to adopt a uniform grouping of counties into administrative districts, as follows:—

1. London and South-Eastern to include London (the City and the Metropolitan Police districts), Surrey, Kent and Sussex.

2. South-Western, to include Cornwall, Devonshire, Somersetshire, Dorsetshire, Hampshire, Wiltshire and Gloucestershire.

3. Eastern, to include Leicestershire, Rutland, Northamptonshire, Huntingdonshire, Cambridgeshire, Norfolk, Suffolk, Oxfordshire, Buckinghamshire, Berkshire, Bedfordshire, Hertfordshire, and Essex; excluding the portions of the last two counties covered by the Metropolitan Police district.

4. West Midlands, to include Shropshire, Staffordshire, Herefordshire, Worcestershire and Warwickshire.

5. East Central, to include Yorkshire (less the Cleveland district), Derbyshire (less Glossop and New Mills district), Nottinghamshire and Lincolnshire.

6. North-Western, to include Lancashire, Cheshire, the Glossop and New Mills district of Derbyshire, and the Isle of Man.

7. Northern, to include Northumberland, Durham, Cumberland, Westmoreland, the Cleveland district of Yorkshire, and the town of Berwick-on-Tweed.

8. Welsh, to include Wales and Monmouthshire.

9. Scottish, to include Scotland.

These districts will, as hitherto, be called "Regions" by the Ministry of National Service, but the Ministry of Labour will refer to them as "Divisions." The Ministry of Labour's term for the Eastern Region will be "South Midlands and Eastern Division."

The Admiralty are unable to make the necessary arrangement for their administrative districts to coincide with the above. They have, however, agreed that for the purpose of labour supply, District Directors of the Admiralty Labour Department will work to the administrative districts agreed upon by the Ministry of National Service, Ministry of Labour, and Ministry of Munitions.

The headquarters of the Ministry of National Service for each of these Regions will be as follows:—

1. London and South-Eastern: Artillery Mansions, Victoria-street, Westminster, S.W. 1.

2. South-Western: 5A, Union-street, Bristol.

3. Eastern: 80, Westbourne-terrace, Paddington, W.2.

4. West Midlands: Queen's College, Paradise-street, Birmingham.

5. East Central: Woodhouse-lane, Leeds.

6. North-Western: New Arts Buildings, University, Liverpool.

7. Northern: 47, Pilgrim-street, Newcastle-upon-Tyne.

8. Welsh: Technical College, Cardiff.

9. Scottish: Royal (Dick) College, Summerhall-square, Edinburgh.

The "Gazetteer" issued by the Ministry of National Service to Post Offices is being amended, and will be re-issued as soon as possible.

The labourers in the National dockyards have, through their unions, made application to the Admiralty to treat the war bonus as a permanent increase of wages, and to grant a fortnight's full pay holiday annually to all Government workers.

The difficulties which have arisen in South Wales in connection with the establishment of Output Committees at the collieries are due to the objection raised by the coalowners to the committees' scope of inquiry. The coalowners object to the workmen having any right to investigate questions of management, through their representatives on the committees. The federation, however, insist that if these joint committees are to deal with questions of output arising through shortcomings on the part of the workmen, they shall also deal with those that arise from shortcomings of the management or from want of proper equipment. Only on this understanding will the federation co-operate in the effort to increase the output of coal.

A meeting of protest against the refusal of the Railway Executive Committee to increase wages was held in Liverpool on August 29. The demand is for a 10*s.* advance, and whilst the speakers protested that they had no desire to fall out with their employers or to impede the work of our armies, the threat was made that drastic action would be taken unless a prompt settlement was effected. A telegram from Mr. J. H. Thomas deprecated hasty action, and suggested that a stoppage might prevent a settlement. Important negotiations were, he stated, in progress.

A conference on Works Committees will be held under the auspices of the Industrial Reconstruction Council on Tuesday, September 10, at 6 p.m., in the Hall of the Institute of Journalists, 2 and 4, Tudor-street, E.C. 4. The subject will be introduced by Mr. Robert Wilson, of the Ministry of Labour, after which the discussion will be open. No tickets are necessary.

The award of the Committee on Production on the claims of tramway and motor omnibus workers was issued during the week. After reviewing the reasons which led up to the granting of war bonuses, the committee point out that the recent advance of 5*s.* per week was deemed to be in full settlement of any claim to the 12½ per cent. The grant made by the Minister of Munitions was at first confined to male workers, and in these circumstances the committee did not feel justified in extending it to women. Since then the Minister of Munitions had granted a bonus of 5*s.* to female munition workers, and the committee had come to the conclusion that the women concerned should have the advance now granted in settlement of any claim to the 12½ per cent. bonus. The committee has decided that women aged 18 or over whose terms of employment include an undertaking that they shall be paid the same rates as the grades of men whose places they have filled shall be paid such an advance as will give 25*s.* per week over the pre-war rates of the grades concerned, and in the case of women not having such agreement the advances shall be increased by 5*s.* per week subject to a maximum of 25*s.* a week over the pre-war rates, the payments to be on the basis of a week of six days of six shifts. The increases take effect from the beginning of the first full pay day following July 9, 1918. They are to be regarded as war wages and recognised as due to abnormal conditions prevailing in consequence of the war.

The committee add that the claim is put forward in such a form as to involve the determination of a general principle applicable, if adopted, not only to women employed on tramways and motor omnibuses, but to women employed in many other industries. Such a principle can be decided only on a national basis, and in view of the far-reaching financial and economic considerations involved the committee recommend that the whole question of women's wages and advances should be made the subject of a special inquiry, in which women can take part and at which all the facts and circumstances can be taken into consideration. The committee approve of the principle that when general changes of wages are under consideration the wages of women as well as men should be considered, and they recommend that the parties should formulate an agreement for a regular procedure for the periodical consideration and review of wages in the industry concerned. It may be noted in this connection that by a recent award women hollow-ware workers in the Midlands receive the largest advance ever conceded in the history of the trade. The basis now is 30*s.* 9*d.* per week.

The Government have decided to appoint a committee to investigate and report as to the relations which should be maintained between the wages of women and men, having regard to the interests of both as well as to the value of their work. The recommendations should have in view the necessity of output during the war and the progress and well-being of industry in the future. The committee will consist of Mr. Justice Atkin (chairman), Dr. Janet Campbell, Sir Lynden Macassey, K.C., Sir W. W. Mackenzie, K.C., and Mrs. Sidney Webb. Lieutenant-Colonel Sir Matthew Nathan (Secretary to the Ministry of Pensions) has been appointed as secretary to the committee.

The Trades Union Congress met at Derby last Monday. The president's address dealt mainly with questions of national or international politics, but contained one very important proposal relative to industrial matters. In order to avoid the disputes as to demarcation of work, which have led to some of the bitterest and most keenly-fought strikes, he suggested the establishment of one great national trade union, with separate officials and departments for the different trades and crafts. Whether this proposal would be an effective method of dealing with the problem can only be settled by trial. There is at least a possibility that the sections may fight over matters of demarcation just as the independent unions do now. Of course, if the general union controlled the strike pay, it would be a strong position for putting pressure on the disputants.

The Controller of Coal Mines announces that the secretaries of the District Coal and Coke Supplies Committees have been authorised to requisition, on behalf of the Board of Trade, coal, coke or manufactured fuel, where it is deemed necessary to do so, in order to secure supplies required to meet any demand

for which it is necessary in the public interest to make provision. In Ireland similar powers are exercised by Mr. H. G. Burgess, the representative of the Controller in Ireland.

Sir Adam Nimmo, K.B.E., the well-known Scottish colliery owner, has accepted an invitation from the Government to assist the Coal Controller in the administration of the coal control. The Government has also invited the Miners' Federation of Great Britain to nominate one of its members to assist the Coal Controller.

As the result of an interview between a deputation of South Wales coke manufacturers and the Ministry of Munitions, relief has been granted them to meet the increased cost of production, due primarily to the special war wage. The authorities agree to grant manufacturers a subsidy of 5*s.* per ton, thus avoiding the task of revising the whole of the controlled iron and steel prices. The subsidy applies only to coke produced for home consumption, and not in respect of supplies exported. The production of coke in South Wales is, in round figures, 1,500,000 tons, and assuming that 1,125,000 tons is consumed at home the subsidy will mean a total of 312,500*l.* per annum for coke manufacturers in South Wales.

The Bradford Chamber of Commerce has received from the Bradford Dyers' Association an offer of 2,000*l.* to 3,000*l.* to be appropriated to the provision of ten travelling scholarships for young men engaged in the study of foreign languages for commercial purposes in connection with the textile trades. The Chamber passed a resolution thanking the Dyers' Association for the offer, and decided to open a fund with the object of raising a further sum of 3,000*l.* for similar objects. Earlier in the war a subscription was started for sending students to Russia to learn the language, but owing to the internal troubles in Russia that scheme has not come into operation, and it was agreed to ask the subscribers to permit the money to be used for languages other than Russian.

An article in last Wednesday's *Times*, written by the English manager of a shipbuilding company at Odessa, gives a most interesting description of the operation of a shipyard under Bolshevist control. When the revolution first broke out, difficulties immediately arose. The employés began to hold meetings where the speakers were of the most extreme type, and amongst these the most rabid were women. At first the management worked fairly harmoniously with the committees, but the demands steadily rose. The sittings became practically continuous, and the representatives, though receiving the maximum pay, did practically no work at all. This maximum pay was about three times the former rate. All piece-work was abolished, and ultimately the output fell to about one-quarter the normal. The question of wages was referred to an arbitration board, which granted the full demands of the men. The meeting habit grew, until gradually most of the day's work consisted of meetings. Later on, Red Guards were formed at Odessa, and a guard was placed over the works. For this "protection" the firm had to pay, the amount being extorted by armed force. These conditions continued for some time, but the yard still carried on. On the fall of Kerensky, a demand for a still further increase of wages was enforced by the argument of arms. A little later the demand was made that representatives of the men should be present at all board meetings. This turned out to be an advantage, as the representatives got to realise the problems and difficulties of the situation, and when they left the meetings tried to reason with their comrades. This, however, soon rendered them unpopular, and led to the appointment of new representatives, who were deposed in their turn and for the same reason. Finally, the works were taken possession of in accordance with a decree of the Bolshevist Government. The six workmen who carried out the decree, expressed regret, saying that their relations with the directors had always been smooth and satisfactory, but "might was right."

According to *The Scientific American*, there is likely to be a general cancellisation of German chemical patents in the United States. It will be remembered that when the attempt was made here to apply certain German patents for the production of nitrates from the air, it was discovered that essential data were omitted, the specification being intentionally misleading, and, therefore, *ipso facto*, invalid. This it appears has now been found to be the case with numerous German chemical patents taken out in the United States. When the authorities there desired to manufacture the products patented, it was found again and again that the processes described in the patents would not work, and American chemists had to solve the problem afresh. The situation thus created is that the German patents are invalid, and if the workable processes devised in America are patented in their turn, Germany may have to pay royalties in the American market on chemicals which she was the first to introduce. This condition of affairs makes it very evident that some reform is needed in the present methods of dealing with patents for chemical products or processes.

A highly curious and possibly significant debate took place at the Trades Union Congress on a motion to substitute the word socialisation for "nationalisation" in the annual motion dealing with the operation and control of mines, minerals, canals and railways. The resolution was carried, as the members appeared to fear that the profits which they somewhat sanguinely expect as a result of nationalisation may be shared by all classes of the nation instead of confined to the workmen directly concerned. On this head the Congress has little to fear: the profits under any possible system of nationalisation will be insignificant, and a matter of little importance whoever gets them. This was realised by one of the speakers, who said it was simply ridiculous to talk of running a socialist railway in the face of more efficiently managed competitive undertakings. The precise idea involved in "socialisation," in contradistinction to nationalisation, was not made very clear, congressional eloquence being often modelled somewhat on the style of Mr. Nupkins, whose ideas, Mr. Samuel Weller admitted, came "a pouring out, knocking each other's heads so fast that seems to stun one another, you hardly know what he's after." "That's the great merit of his style of speaking," rejoined Mr. Muzzle. The merit may certainly be claimed for more than one of the speakers last Tuesday. As far as can be gathered, however, the idea is that, if socialised, there will be practically no profits at all, as the workers would get the benefit. If this means that all industrial undertakings are to be taken over by the workmen concerned in them, the distribution will involve considerable inequalities. To provide work for one man on British railways necessitates a capital expenditure of about 2,000*l.* In the engineering trades the corresponding figure is about 200*l.*, in the cotton trade about 150*l.*, whilst in waterworks and power stations the capital sunk varies from about 350*l.* to 500*l.* per man employed. In mines it is below 180*l.* Such a resolution as is proposed would accordingly be equivalent to endowing each railway man with about 2,000*l.*, whilst the miner or mechanic would get only one-tenth the sum.

COAL DISCOVERIES IN IRELAND.—Further discoveries of coal have been made in the Irish midlands, and departmental inspectors are examining the recently discovered seams in King's County and elsewhere which promise to give an abundant yield. In King's County, several seams have been discovered within a month.

MERCHANT SHIPBUILDING OUTPUT.—AUGUST, 1918.—The tonnage of merchant vessels completed in United Kingdom yards and entered for service during August, 1918, compared with preceding periods, is given below:—

Month.	Gross Tons. 1917.	Gross Tons. 1918.
January	48,089	58,56b
February	79,451	100,038
March	118,699	161,674
April	69,711	111,533
May	69,773	197,274
June	109,847	134,159
July	83,073	141,948
August	102,060	124,675
Total, eight months to August 31	680,703	1,029,869
Total, twelve months to August 31 ...	928,470	1,512,640

The Controller-General of Merchant Shipbuilding makes the following comments: "The reduction from July is partly still attributable to influenza in the yards. Minor fluctuations from month to month, however, are unimportant compared to the general trend of the figures. The plans made to increase skilled labour in the yards have been frustrated by the events of the past four or five months on the Western front, and it has been impossible to provide skilled men for the yards in increasing numbers. I am pleased to say, however, that there is early probability of a reduction of the present naval programme, which will result in a transference of men to merchant work. By the co-operation of my colleagues in the Admiralty, from whom I receive at all times the fullest possible assistance, and in continuance of the policy of my predecessor, I have been able materially to improve the situation in the yards in preparation for increased output. I have returned from extended tours of inspection of all the principal shipbuilding centres, and I am confident that the foundations are being well and surely laid for an increased output towards the end of the year. I am of the opinion that the output will then improve materially. This will especially be the case as skilled men are placed at my disposal, enabling the merchant yards to absorb unskilled men whom to-day we are unable to place on account of the lack of skilled men."

TESTING AIR COMPRESSORS.

TO THE EDITOR OF ENGINEERING.

SIR,—I have been much interested in the correspondence published in your recent issues relating to the above, and would like if you could spare me a little space to make a few remarks which Mr. Tennant and the other correspondents might find interesting. The published test was, according to Mr. Tennant, principally a no-load test, and as such was most successful, indeed the results were far better than anyone acquainted with air compressor design would have expected. "W. W. F." states that we are behind the Americans in our methods of unloading our compressors, and advocates the holding open of the first stage air-inlet valves and allowing the air to be drawn in and discharged to atmosphere. I agree with him were this practicable, but in the design in question, where there are a number of inlet valves, it would be a most difficult matter to arrange. It could, of course, be easily overcome by fitting separate unloading valves of sufficient size on the first-stage cylinder and operating them by the air governor, and these, combined with similar valves on the second-stage cylinder would, without doubt, give the best results as regards no-load power. Mr. Tennant points out that these additional fittings are objectionable, and I am inclined to agree with him, for the power thus saved would be very little, and unless a compressor is to be a long time under no-load conditions it would not be worth while fitting them. The makers of Mr. Tennant's compressors have, I think, fitted some of their machines with an unloading valve on the final discharge, but perhaps they have discarded this practice for the above reasons. In the published test, however, there are results given which are of much greater importance than the no-load results and these are the output of 4,120 cub. ft. of air to 80 lb. pressure per square inch, and the power taken to do this, namely, 655 brake horse-power. These figures, of course, could not be questioned by anyone not knowing the dimensions of the cylinders, &c., which Mr. Tennant has now, at the request of his correspondents, kindly given us. The power required to compress the air need not be doubted, but owing to the difficulty in measuring the air output from a compressor, the figure 4,120 cub. ft. requires some corroboration. What determines the amount of air a cylinder of a given diameter and stroke can deliver is principally the amount of clearance volume at the end of the stroke, and that is fixed by the size of the ports necessary to allow the air to be taken in and discharged at a reasonable speed. Any other theory, such as surging at the inlet due to manipulating the length of the intake pipe, can safely be neglected. A 36 in. diameter by 17-in. stroke intake cylinder, running at 243 r.p.m., would represent a volume swept of approximately 4,860 cub. ft. The actual volume of free air delivered being 4,120 cub. ft., the compressor would thus show a volumetric efficiency of 85 per cent., which I think is too good when I consider that the clearance volume of a machine of this design would be nearly 15 per cent. of the volume swept. Assuming the clearance to be 15 per cent. and the final air pressure in the intake cylinder to be 28 lb. per square inch (see low-pressure cards), also that the clearance volume air expands, say, midway between the isothermal and the adiabatic curves, a simple calculation gives us a permissible volumetric efficiency of 78 per cent., and that is not allowing for any leakage losses, or slip past the air valves. This would mean that the maximum amount of air one could expect from a machine of this type would be about 3,800 cub. ft.; omitting, as I say, the leakage and other losses. I agree with Mr. Tennant that it is a pity that there is no reliable manner in which to test the output of an air compressor, as it leaves the buyer too much in the hands of the makers, but after all, the output can be checked in the manner I have described, and in this example the calculated capacity would, from my experience, be more in keeping with the 655 brake horse-power quoted.

I am,

"INTERESTED."

81, Calder-street, Croshill, Glasgow.

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANTS."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with much interest the letter of your correspondent "Research," in the issue of August 23, 1918. The great majority of boiler plants in this country are being run almost entirely in the dark as regards their performance. It is, of course, impossible to give exact figures, but certainly in my opinion over 90 per cent. of the coal burnt under steam boilers, that is over 67·5—90,000,000 tons on the total consumption of, say, 75,000,000 tons to 100,000,000 tons per annum, is being consumed without proper means of scientific control. I quite agree with your correspondent's remarks concerning rule-of-thumb manner in which additional boilers are installed without first making sure that sufficient steam is being obtained from the existing boilers, and this is one of the results of our lack of scientific methods in industry.

With regard to the question of what we may call for the want of a better word "Government interference" with the running of boiler plants this is, of course, a very delicate matter. No doubt your correspondent will be much interested in the steps now being taken by the American Government, of which I gave a *résumé* ("Fuel Economy in the United States") in the issue of August 23, 1918.

I presume that eventually it will have to be more or less recognised in the country that our coal is national wealth that will not last for ever, and to waste it is to do the whole country an injury.

The natural result of this recognition will be that the

more wasteful plants will need to be controlled in some way by the Government, but the trouble will be to carry out this policy efficiently.

In reply to the letter of your correspondent, Mr. John H. Anderson, I do not think that the 250 plants we have examined are really better than the average, at any rate judging from the many hundred boiler plants we have examined superficially without testing. Naturally, if we could give the results of, say, 1,000 plants, the case would be stronger, but until such time as more extended information is available I think 60 per cent. efficiency will prove to be a very good average. The question of skilled stokers is one of the great troubles of steam production, but owners of boiler plants generally have been most difficult to convince on this question. It was almost childish to expect a boiler fireman to carry out efficiently and intelligently the laborious and unpleasant task of burning in steam boilers say 45 tons of coal per week, worth, say, 35*l.* to 40*l.*, for the sum of 25*s.* to 30*s.* per week, taking pre-war conditions. We have not dealt with any other section of the question of coal saving except that of producing the steam efficiently at the boiler stop valve from the coal in the fire-hole, but I quite appreciate Mr. Anderson's remarks on other important sections of the question.

Your correspondent "Morgan" also deals with the question of the quality of the stoking, and emphasises the above conclusions. With regard to the question of the difficulty of firing 8 ft. diameter "Lancashire" boilers, or over, the question of the height of the firing level from the floor can easily be got over by raising the floor in front of the boilers to any desired amount to suit the fireman. Also the length of the grate has nothing to do with the diameter of the boiler. Thus taking average figures an 8 ft. diameter "Lancashire" boiler has a grate width of, say, 3 ft. 2 in., which, with a grate length of, say, 5 ft. 6 in., gives a total grate area per boiler of 34·62 sq. ft. With a consumption of 35 lb. of coal per square foot of grate area this corresponds to 1,218·8 lb. of average-quality coal per boiler per hour, which, with an evaporation of, say, 8 lb. of water per pound of coal, gives an evaporation of 9,750 lb. of water per hour.

There is no need to have grates anything like 7 ft. 6 in. long, and probably such a grate would evaporate very little more than one, say, 5 ft. 6 in. to 6 ft. long, apart from the great difference in efficiency.

With regard to the question of boiler settings there are a number of improved makes now on the market, most of which achieve much better conditions as regards freedom from leakage and amount of area in contact with the plates as compared with the old-fashioned seating blocks.

In reply to your correspondent "J. W.," I do not think that it is altogether correct to calculate the rate of evaporation per square foot of heating surface of the boiler only, but that it would be much more accurate to include the heating surface of the whole plant, that is boilers, economisers and super-heating surface. Also I do not understand the statement of your correspondent that the maximum efficiency of combustion is obtained when burning fuel at 16 lb. to 24 lb. per square foot of grate surface, according to the draught available and provided the amount of air supplied is controlled.

Apart from the question of the quality of the fuel, if the amount of air supplied can be controlled exactly it is possible to get the maximum efficiency with skilled stoking with any reasonable rate of combustion, say, from 15 lb. to 35 lb. per square foot grate area per hour. Taking, however, everyday ordinary conditions of stoking and average quality of coal, I should say the best figure is much more like 25 lb. to 30 lb. per square foot grate area per hour than 16 lb. to 24 lb. as given by your correspondent.

Yours faithfully,

August 31, 1918. D. Brownlie.

To the Editor of Engineering.

Sir,—In the very able exposition of this subject by Mr. D. Brownlie, B.Sc., F.C.S., published in Engineering, July 12 and 19, brief but somewhat disparaging reference is made as to the economic utility of coke as fuel for boiler firing. This reference is not only misleading to your readers, but does not fairly represent the true facts. Mr. Brownlie states that, of the 250 steam boiler plants tested by him or his firm, 190, or 76 per cent., were hand-fired, with an average net working efficiency of 57·8 *per cent.*

The writer's experience tends to confirm these figures so far as *coal*-fired boilers are concerned, but the following extracts from Messrs. Brownlie and Green's report on the working of a *coke*-fired plant at a London factory should, in common fairness to more enlightened steam users and coke manufacturers, receive due publicity:—

"Dimensions of boilers, 28 ft. by 7 ft. 6 in.

"Duration of trial, 9 hours; check trial, 1 week.

"Coke burned per square foot of grate per hour, 22·59 lb.

"Water evaporated per boiler per hour, 5,093 lb.

"CO_2 in flue gases, 14 per cent., average of one week's continuous run.

"Percentage of CO, nil.

"Temperature of exit gases—average, 377 deg. F.

"Remarks.—When the increase of efficiency due to the superheaters is allowed for, and also the loss in efficiency due to using 3 per cent. of the steam under the fire-bars, the real net efficiency of the plant works out at 86 *per cent.*

"The plant is burning a medium amount of fuel (about 50 tons per week); 5,093 lb. of water per hour on boilers 28 ft. by 7 ft. 6 in. is about the correct evaporation for maximum efficiency. It would be possible to force the plant to evaporate more than this, but the efficiency would suffer.

"The net efficiency of the plant (86 per cent.) is remarkably high, and we may say is the very best result we have ever obtained in testing boiler plant.

"The economisers are working fairly effectively, 5·7 per cent. of the fuel bill being saved. It must, of course, be remembered that with your system of coke firing the amount of heat which gets past the boiler is comparatively small, and although it is possible to save 20 per cent. of the fuel bill with coal fires by installing economisers, this is not the case with coke fires.

"The range of draught obtainable with your system is ample, and the amount of steam used is only 3 per cent., which is an extremely efficient arrangement. An induced draught fan would take 2½ per cent. to 3 per cent. of the steam, even if well looked after.

"This test has been carried out under the normal everyday working conditions of the plant. The actual average heating value of several samples of the damp coke was determined by the Mahler-Donkin oxygen-bomb calorimeter.

"The plant is the most efficient we have ever tested, and it will be quite impossible for us or for anyone else to devise any improvement whatever in the working. In our opinion the plant is extremely well looked after, and the firing could not be improved, which accounts for the extremely high efficiency.

"(Signed) Brownlie and Green,
"Manchester."

Since fitting up the boilers referred to in this report with the London Coke Committee's system of forced draught, which cost then only 12*l.* 12*s.* per boiler, it has been the writer's privilege to instal nearly 400 sets of this apparatus on all types of steam boilers in and around London. These are consuming over 200,000 tons of locally-produced coke per annum, to the total exclusion of an equivalent tonnage of rail-borne coal, and, while it is not suggested that there is sufficient coke available to replace all the bituminous coal used for steam-raising, a large number of relatively inefficient coal-fired steam plants, both hand and mechanically stoked, might readily be improved by adapting them to use coke, considerably increased quantities of which would probably become available if the diversion were effected to gas works of bituminous coal supplies which are now more or less wastefully used as boiler fuel.

Yours faithfully,

E. W. L. Nicol,
Engineer and Fuel Expert, London Coke Committee.

84, Horseferry-road, S.W. 1, August 29, 1918.

To the Editor of Engineering.

Sir,—Everyone interested in the conservation of coal (and in these days that means the nation at large) owes a debt of gratitude to Mr. Brownlie for the masterly paper advocating the more scientific management of steam-raising plants, which recently appeared in Engineering.

The authorities are now appealing by poster to householders to save pennyworths of coal. In view of the fact that Mr. Brownlie's figures, patiently collected during eight years, and based on the working of 250 steam boiler plants, show conclusively that we are wasting at least *fifteen million tons* of coal per year by careless methods in the boiler-house, would it not be more to the point for the Coal Conservation Committee to send a reprint of the paper to every steam user in the United Kingdom?

That might bring home to the patriotic majority the disquieting fact that by neglecting to ensure the utmost possible efficiency from coal, steam users are wasting, on a truly appalling scale, our most precious asset.

Yours faithfully,

J. P. O'Callaghan, F.C.S., Memb.Soc.Chem.Ind.

20, Lincoln's Inn Fields, London, W.C. 2.

ENGINEERING PROPAGANDA.

To the Editor of Engineering.

Sir,—At the present time, when so much is being advocated with regard to trade and scientific propaganda in neutral countries, I should like to draw attention to one point of the engineering aspect, and indicate how the Germans still seem to do better than us.

In most of the official organs of the engineering and trade societies in neutral countries, it is usual to print a list of the technical publications received, week by week, or month by month. On perusing some of these publications lately I was surprised to find British technical journals considerably in the minority. German publications of all kinds figured largely, and even the French had a more representative list than the British. I am not aware, of course, whether the neutral countries' societies purchase the German publication, or whether they receive it by way of exchange; but in the case of a society not endowed with ample funds, probably the latter course is followed.

As I can hardly think English engineering publications would not be welcome in the reading rooms of such societies, I have reluctantly come to the conclusion that British societies and publishers have not found it profitable to arrange for such exchanges. The natural consequence must be that neutrals will have to rely largely on extracts in German and other publications for their knowledge of progress in engineering in this country. Provided arrangements can be made with the British Government, I suggest that steps be taken as soon as possible to remedy this state of affairs, in order that engineers and others in neutral countries may be correctly informed of British opinion and progress. The expense would be small compared with the gain to British prestige.

I am, yours faithfully,

E. S. Hodgson,

Coventry, September 3, 1918.

TOLERANCES OF FINE-SCREW THREADS.

The British Engineering Standards Association has recently issued a new report,* No. 84, 1918, on the Tolerances of British Standard Fine (B.S.F.) Screw Threads, those given in the previous report, No. 38, being thus superseded. In the preface to this new publication it is pointed out that the experience of the past ten years has shown that whilst the series of British Standard Fine (B.S.F.) screw threads introduced by the committee in 1908 are well suited to the purposes for which they were designed, the tolerances given in report No. 38 were too small for commercial work, and the report in consequence has been but little used.

The present report gives new tables of tolerances for B.S.F. bolts and nuts which it is believed will meet present needs. The association has in preparation similar tables for the British Standard Whitworth (B.S.W.) and the British Association (B.A.) threads, and it is hoped that these may be available very shortly. The tolerances laid down are those which the experience of the past few years has shown to be suitable, and the opportunity has been taken to emphasise the need of a closer fit on the flank of the thread by giving larger tolerances on the crest and root than on the effective diameter. Two classes of fit are provided for, namely the Standard B.S.F. tolerances and a second series of tolerances formed by halving the standard tolerances everywhere. Threads made in accordance with these latter dimensions are to be known as British Standard Fine Threads (Close Fits).

An additional screw has been included in the B.S.F. series to meet the need of the aircraft industry for a smaller B.S.F. screw than the ¼-in. size, namely $\frac{7}{32}$-in. diameter, with 28 threads per inch. The report is accompanied by two appendices. Appendix I gives an explanation of the terms "grade" and "play" as applied to a screw thread which are now employed by the association for the first time. These two quantities are determined from the diametral errors produced by errors in angle and pitch combined with the error in effective diameter and a description of a graphical method of obtaining them is given and illustrated by a nomograph chart. Appendix II shows how the formulæ for determining the reduction in effective diameter required to compensate errors in angle and pitch are obtained.

The present report is largely intended for the guidance of inspectors, and the association has in preparation a further report giving tables for the use of manufacturers of screws, and showing the alterations to the effective diameter consequent upon variations in the angle and pitch within the limits laid down in the present report.

British Tungsten.—In a lecture recently delivered at the Scientific Products Exhibition, Mr. J. L. F. Vogel said that before the war some abortive attempts had been made in England to establish the manufacture of tungsten on a commercial basis. He himself had been connected with Dr. Stenhardt in running a small factory in London, where about 300 tons were manufactured, but it was impossible to meet the German competition, and the company lost money. Thanks to the Navy, Germany since the war had experienced almost a famine in tungsten. When war broke out there was only a four months' supply in this country, but a factory was started, and one of the most serious problems with which munitions makers were faced—the shortage of tungsten—had been solved. He believed that the industry could be maintained in this country if it were given a fair chance. The gravest danger it had to face was post-war competition, but there was an ample supply of raw material in the Colonies, and the essential plant was in England, so that if the Government's post-war policy was all right, there was a great future before the industry, as there would be a great commercial demand for tungsten.

Captured Enemy Aircraft.—It would be difficult to imagine a more interesting and informative technical museum than that which has been organised at the Agricultural Hall, Islington, by the Controller of the Technical Department, Aircraft Production, Ministry of Munitions. It comprises examples of nearly all the types of German aeroplanes which have been captured during the war, and thus represents very completely the development of enemy aircraft design. The object served by the museum is twofold, firstly to enable designers and constructors to keep in close touch with what their German rivals are doing, and secondly to provide our pilots and cadets with first-hand information which will not only help them to recognise hostile machines, but will also indicate their most vulnerable points. For these purposes all the aeroplanes are treated in the same manner, one-half being entirely stripped so as to expose any structural detail, the other half left intact. Amongst the numerous exhibits may be mentioned the Friedrichshafen and Gotha bombing planes, the Fokker biplane and triplane Scouts, and the Hannoveraner and Halberstadt fighters. The museum is replete with all manner of enemy aircraft accessories, including engines of all types. The latter are shown both complete and in sectional form. Passes to view the museum, which is not open to the public, are issued to O.Cs. commanding units for the use of officers and men serving under them, and to firms engaged in the aircraft industry for the use of their employees, by the Controller, Technical Department.

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* The report can be obtained from the British Standard Association, 28, Victoria-street, London, S.W. 1, or from the publishers, Messrs. Crosby, Lockwood and Son. The price is 1*s.* (postage 2*d.*).

THE METALLOGRAPHY OF TUNGSTEN.*

By ZAY JEFFRIES,† B.S., Met. E., Cleveland, Ohio.

(*Continued from page 242.*)

EFFECT OF CHANGE OF TEMPERATURE ON THE STRUCTURE OF TUNGSTEN INGOTS.

Since a temperature of 3,200 deg. C. produces the germinative conditions at the axis of a tungsten ingot containing 4 per cent. thoria, a fine-grained structure would be produced by heating to temperatures lower than about 3,150 deg. C. The germinative temperature of a tungsten ingot containing 5 per cent. thoria, or more, is theoretically above the melting-point of tungsten, so it is non-existent.

A tungsten ingot containing 2·5 per cent. thoria has its germinative temperature near the surface of the ingot when a mean temperature of 3,200 deg. C. is maintained. Therefore, if the temperature were lowered to about 3,100 deg. C., the germinative temperature would occur near the axis in this sample. If, however, the temperature could be increased to 3,300 deg. C. before germination had begun during heating, a fine-grained structure would result, which would correspond to the normal equilibrium grain size in the growth range for the given time and temperature conditions.

With the sample containing 1·5 per cent. thoria, a mean temperature of 3,200 deg. C. was sufficient to make every part of the cross-section of the ingot above its germinative temperature. If the temperature could have been lowered to, say, 2,900 deg. C., germinative conditions would have obtained in this sample with the resultant production of a coarse-grained structure. The germinative temperature of tungsten ingots containing 0·75 per cent. thoria is about 2,550 deg. to 2,650 deg. C. This germinative temperature is so low for tungsten that the individual particles of the tungsten powder must be very small or the formation of large grains at the germinative temperature will be defeated.

Some tungsten powder was prepared consisting of grains or particles very much smaller than the size usually employed. Experiments were made with tungsten ingots pressed from this very fine tungsten powder. It was found that the germinative temperature occurred at about 2,600 deg. C. The time necessary to produce a marked coarsening of the grain at the germinative temperature was very much longer in this material than with material whose germinative temperature was in the neighbourhood of 3,200 deg. C.

Fig. 21 represents the fracture of one of these tungsten ingots heated for 20 minutes at a temperature near 2,600 deg. C. Fig. 22 is the fracture of an ingot treated at a temperature of about 2,600 deg. C. for 30 minutes. In both of these photographs, the coarse-grained areas can be seen in the region midway between the axis and the surface of the sample. The axis itself is fine-grained and the surface is fine-grained.

Fig. 23 is a fracture of one of these tungsten ingots which was heated quickly to a temperature of 3,200 deg. C. and held for 30 minutes. The structure is fine-grained and uniform.

Fig. 24 is a micrograph of a tungsten ingot held at 2,600 deg. C. for 20 minutes.

Fig. 25 shows the cross-section of an ingot heated to about 2,600 deg. C. for 30 minutes. The fine-grained portions near the surface in both these samples is finer grained than that near the axis.

Fig. 26 is a longitudinal section through section A A of the same ingot as Fig. 25.

Fig. 27 shows how the germinative temperature conditions produce coarse-grained structures at the ends of the ingots which are held in the electrodes. There is a temperature gradient at the ends of the ingots, because the electrodes are either directly or indirectly water cooled so that a change of temperature of at least 2,000 deg. is maintained between the portion of the ingot held in the electrode clamp and the hottest portion. Fig. 27 shows where the germinative temperature existed. To the left of the coarse-grained region may be seen the inert region, and to the right the gradual change of the coarse-grained area to a normal fine-grained structure. It is needless to say that the sintering temperature of this ingot was far above its germinative temperature.

Fig. 28 shows the structure of a tungsten ingot, heated quickly past the germinative temperature and held there for 30 minutes. Any intermediate structure between the coarse-grained structure formed at the germinative temperature and the normal fine-grained structure formed by heating quickly through the germinative temperature range can be produced by varying the time in which the ingot remains in the germinative temperature range during heating—that is, by varying the rate of heating.

Figs. 29 and 29A are micrographs of a tungsten ingot which was held for 20 minutes at 2,600 deg. C., and then heated quickly to 3,200 deg. C. and held there for 10 minutes. The grain size of this sample is very much coarser than the normal grain size formed by rapid heating through the germinative temperature range and much finer than the grain size which was formed by a long sojourn in the germinative temperature range.

The smallest grain size that can be produced in an ingot will depend upon the size of the tungsten particles composing the tungsten powder. At the time these particles weld themselves together (sinter), the smallest grain size which it is possible to obtain from this tungsten powder will result. A tungsten ingot in this condition, however, finds very little use in the industries. It is too fine-grained to be easily amenable to the tungsten working process, especially when it is desired to secure a great amount of permanent deformation. For example, a tungsten ingot treated in this manner can only be swaged and drawn with the greatest difficulty from an ingot ¼ in. square to a small drawn wire. Such a metal is so hard that the diamond die wear may be 50 times as great during drawing as that of tungsten ingots composed of larger grains.

By heating the tungsten ingot just above the germinative temperature, the smallest grain size in the growth range is produced. It is only in the growth range that the tungsten ingots lend themselves readily to the mechanical working process. As the temperature increases, the grain size of the tungsten ingots increases up to the melting-point of the tungsten.

The relatively coarse tungsten powder ordinarily employed in the manufacture of tungsten ingots is sufficiently coarse grained to mask the germinative temperature phenomena in the 0·75 per cent. thoria ingots during sintering. In these ingots, the grain size starts at a minimum at about 2,600 deg. C. and gradually increases up to the melting-point. A typical set of results is shown in Diagram B overleaf. The curves show the variation in grain size in tungsten ingots due to variation in the pressure to which the tungsten powder is subjected, and to variation in the temperature to which the tungsten is heated. We may call a pressure of 30,000 lb. to the square inch a normal pressure. The grain size of an ingot sintered for 12 minutes at 2,500 deg. C. will be about 80,000 grains per square millimetre. At 2,600 deg. C., the grain size is the same. This indicates that below 2,600 deg. C. tungsten containing 0·75 per cent. thoria is in its inert range. The grain size will become progressively larger as the temperature is increased above 2,600 deg. C., so that at 3,200 deg. C. a grain size of 5,000 per square millimeter or less will usually result with tungsten metal containing 0·75 per cent. thoria.

By increasing the pressure used in making the compressed tungsten slug to 200,000 lb. per square inch, the grain size becomes larger for any given temperature of treatment, as shown in Diagram B. The use of 200,000 lb. pressure in practice, however, is not only an extremely difficult task to perform but it is absolutely unnecessary for the accomplishment of any given purpose; for

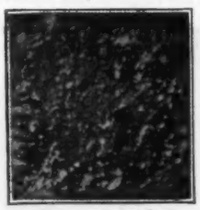


FIG. 21.

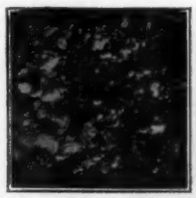


FIG. 22.

FIG. 23.

FIG. 21. TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED 20 MIN. AT 2,600 DEG. CENT. × 5.

FIG. 22. TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED 30 MIN. AT 2,600 DEG. CENT. × 5.

FIG. 23. TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED QUICKLY TO 3,200 DEG. CENT. AND HELD FOR 30 MIN. × 5.

FIG. 24. TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED 20 MIN. AT 2,600 DEG. CENT. TRANSVERSE SECTION. × 9.

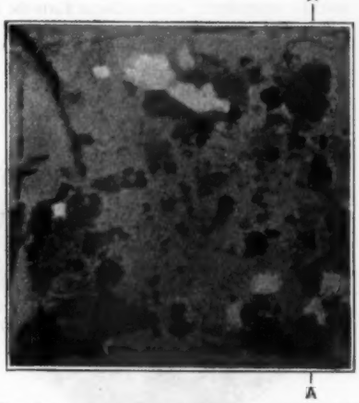


FIG. 25. TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED 30 MIN. AT 2,600 DEG. CENT. TRANSVERSE SECTION. × 9.

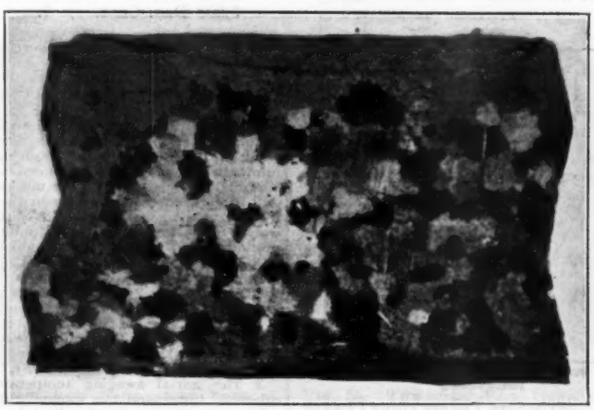


FIG. 26. LONGITUDINAL SECTION AT SECTION A–A OF FIG. 25. × 9.

* Paper submitted for discussion by the American Institute of Mining Engineers.

† Director of Research, Aluminium Castings Company.

example, any result produced with 200,000 lb. per square inch pressure can be duplicated at a higher temperature with a smaller pressure.

The tungsten powder is partly amorphous and partly crystalline. The crystalline particles are probably strain-hardened by the pressure, but these strains play little part in the grain growth. They are removed before sintering takes place. The reason that high pressure tends to make larger grains is that the tungsten particles are pressed into more intimate contact, thus facilitating grain growth.

By comparing Diagrams A (page 240, *ante*) and B, it will be observed that the increase in resistance to grain growth of about 4 per cent. thoria is equivalent to the decrease in resistance to grain growth due to lowering the temperature about 300 deg. C.

Changes in Grain Size due to Incomplete Fusion of Tungsten Ingots.

Tungsten ingots containing about 0·75 per cent. thoria remain comparatively fine-grained even up to the melting-point. Fig. 30 is a micrograph of one of these ingots in which the central portion has fused and re-solidified and the outer portion has remained entirely in the solid state. Fig. 30A represents the same structure at a higher magnification. We have been taught that when fused metal at the time of solidification is in contact with crystalline metal of the same composition, this latter will act as a nucleus about which the molten metal will crystallise and assume the same orientation as the crystalline nucleus. In Fig. 30, when the tungsten was molten, it was in contact with hundreds of the small grains composing the unfused portion of the ingot. When solidification began, why did not each one of these small differently oriented grains act as a nucleus for the crystallisation of the molten tungsten? They probably did. If the crystallisation of the fused tungsten began from many points with different orientation, why was the resulting structure so coarse-grained as that shown in Fig. 30? The answer in my opinion is as follows: When a molten metal is in the process of solidification, it is in its most susceptible condition for grain growth. In other words, the possibility of one grain absorbing adjacent grains in an almost inconceivably short time is greater at the melting-point of a metal than at any other temperature. Let us suppose that the crystallisation of this fused tungsten began at the contact between the fused and the unfused portion. This must necessarily have been the case. The small grains would grow axially, and if no grain growth could take place during the solidification, each of these grains would form a wedge, the small end being at the axis of the ingot. This has not taken place. Some of these grains having advantages over their neighbours, have acquired crystalline material from the molten metal faster than others. These more vigorous grains have shot out arms perpendicular to their axes of growth and have absorbed not only the molten metal which should have gone to some of the other nucleii, but also some of the crystalline material which had solidified on other nucleii. In this manner only a few of the more vigorous grains have survived.

Fig. 31 shows that if the original structure of the ingot is coarse-grained instead of fine-grained, the fused central portion will resolidify strictly in accordance with the laws of the initial nucleii. For example, it will be seen that every grain in the unfused portion has its continuation in the portion which fused and subsequently resolidified. There is no reason to suppose that at the beginning of solidification of Fig. 30, crystallisation did not start from each and every small grain which was in contact with the fused metal. This leads us to the conclusion that in cast metals, the grain size does not depend entirely on the number of nucleii from which crystallisation begins, but that grain growth takes place at a remarkably fast rate during solidification.

Tungsten and Carbon.

Tungsten in the Presence of carbonaceous gases at high temperatures, or in contact with solid carbon at high temperatures, forms tungsten carbide, generally W_2C Tungsten containing even small amounts of tungsten carbide at the boundaries of the grains is extremely brittle and fragile both at room temperature and at high temperatures. It has not been possible mechanically to work tungsten ingots containing tungsten carbide as a net work. Fig. 32 is a micrograph of a tungsten ingot made by adding 0·9 per cent. carbon in the form of lamp-black to the tungsten powder before pressing. The tungsten carbide is the lighter constituent surrounding the grains of pure tungsten. This material is brittle, both hot and cold.

When too much carbon is added, the tungsten ingot, especially if thoria is present in the tungsten powder, will burst during the sintering operation. Fig. 33 is a photograph showing one of the bursted ingots containing carbon and a normal tungsten ingot without carbon.

If a piece of tungsten metal is heated to a temperature of 1,800 deg. C., in contact with solid carbon or in the presence of carbonaceous gases, tungsten carbide forms readily at the surface of the sample. Carbon containing gases will act more quickly and at lower temperatures than solid carbon. Hydrocarbons may form tungsten carbide in contact with metallic tungsten at temperatures as low as 1,100 deg. C. Fig. 34 shows a piece of tungsten that was heated for 1 hour in an electric furnace in an atmosphere of CO. The lighter portion is the tungsten carbide which forms on the surface. The darker portion is pure tungsten. Fig. 35 shows a piece of tungsten metal heated for 1½ hours at a temperature near 1,800 deg. C., the tungsten being placed on a platform of carbon while an atmosphere of hydrogen was maintained in the furnace. The lighter portion is tungsten carbide. The depth of carbonisation increases with increase in time. In 1½ hours the depth of carbonisation was 0·21 mm. and in 3 hours 0·30 mm. at 1,800 deg. C.

It has been found possible mechanically to work tungsten containing a considerable amount of tungsten carbide when the carbide was made separately, powdered, and added to the tungsten powder before pressing. Tungsten ingots made up containing tungsten carbide in this manner may be mechanically worked when the carbon content is far in excess of that necessary to make the tungsten brittle ordinarily. When added in this way, the tungsten carbide does not surround the tungsten grains.

General Considerations Regarding the Working Properties of Tungsten.

The sintered tungsten ingots are usually comparatively fine-grained, say from 1,500 grains to 5,000 grains per square millimetre. It is considered desirable at present to keep the grain size of the ingots comparatively small because the inherent resistance to grain growth will usually give better life properties to the tungsten wire when used for lamp filaments. It is easily possible, however, to get the grains too fine for proper mechanical working. The more thoria or other non-metallic materials present, the more does fineness of grain militate against the mechanical working. With 0·75 per cent. thoria, which is the amount ordinarily used, if the grain size in the ingot is more than about 7,000 per square millimetre, the metal will be extremely hard to work, especially in the smaller sizes. It is usually advisable to keep the grain size below 6,000 per square millimetre. Tungsten ingots have been worked containing as high as 30,000 grains per square millimetre, but the metal is so hard that it is impracticable to work it as a commercial process.

With very coarse-grained structures—for example, with ingots containing grains each of which measures several square millimetres in area—the first stages of the mechanical working process are very apt to break the metal. If one of these coarse-grained ingots passes the first eight or ten pairs of swaging dies, the rest of the working process is comparatively easy—in fact, easier than the working of the tungsten rods made from finer-grained ingots.

If it is desired to produce ductility in tungsten with a comparatively small amount of working, the following processes may be resorted to:—

Fig. 27.

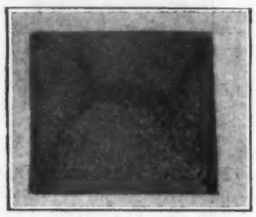


Fig. 28.

Fig. 27. Longitudinal Fracture of Tungsten Ingot Containing 0.75 per Cent. ThO_2. Cold End in Electrode Clamp. × 5.

Fig. 28. Tungsten Ingot Containing 0.75 per Cent. ThO_2, Heated Quickly to 3,200 Deg. Cent. and held 30 Min. × 5.

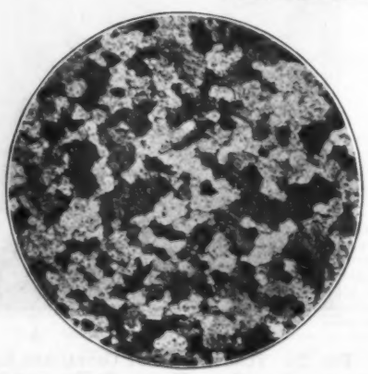


Fig. 28A. Tungsten Ingot Containing 0.75 per Cent. ThO_2, Heated Quickly to 3,200 Deg. Cent. and held 30 Min. × 144.

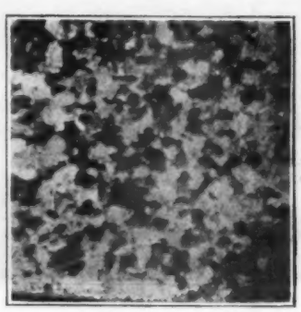


Fig. 29. Tungsten Ingot Containing 0.75 per Cent. ThO_2, Heated 20 Min. at 2,600 Deg. Cent. and then Heated 10 Min. at 3,200 Deg. Cent. × 7.

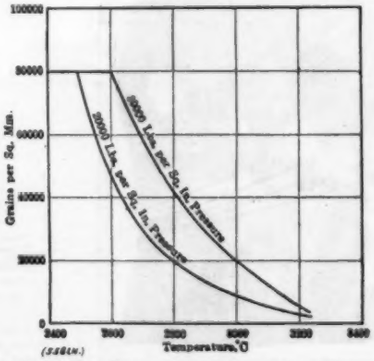


Diagram B. Grain-Size Temperature Curves of Tungsten Briquettes. Figures refer to Initial Pressure used in Briquetting. Time of Heating, 12 Min.

1. The working should be carried on at as low a temperature as possible.

2. The grain size of the ingot should be as small as will permit mechanical working without causing excessive trouble.

Either method, or both of the methods carried out simultaneously, will produce the desired effect, but the resulting product, which has been made ductile with a minimum amount of mechanical working, is not a suitable material for further mechanical working. It will be so hard that it will wear the dies unduly, and, furthermore, it will break and split easily during the working. What is more apt to be desired than the production of ductility in tungsten with a comparatively small amount of mechanical working is the possibility of working the tungsten a great deal before it becomes too hard and intractable for further working. This end is accomplished in several ways:—

1. The grain size of the sintered tungsten ingot should be less than about 6,000 grains per square millimetre.

2. The working temperature at the beginning of swaging should be very high, say, 1,700 deg. C.

3. The initial swaging temperature may be considerably lower and the swaged tungsten rod can be subjected at intervals to a heating process which will cause the distorted grains formed by working to change into equiaxed grains, thereby forming a structure usually somewhat coarser-grained than that of the ingot. The equiaxed tungsten rod is then capable of a greater amount of mechanical working at the proper temperature than it would have been had it not been equiaxed.

If it is desired to produce a piece of tungsten which is ductile at a particular size, this may be accomplished in the following ways:—

1. By starting with a coarse-grained material of such a size that it will take a considerable amount of mechanical working to reduce it to the desired size.

2. By starting with a fine-grained material of such a size that a moderate amount of mechanical working, say an elongation of 25 times its original length, will reduce it to the desired size.

3. By starting with smaller sizes than would be used

with (1) and (2) and performing the mechanical working operations at temperatures as low as possible.

The reasons for the above generalities have been largely ascertained and will be considered later.

From the time the tungsten wire reaches a diameter of 0·030 in. (0·76 mm.) or less, it is handled on reels. It would not be at all convenient, at any stage in the fine-wire manufacture, to heat it to such a temperature that the fibrous structures to which tungsten owes its ductility are destroyed. Such an operation would make the wire brittle, and it could not be handled on reels in lengths of a mile or more at room temperature (as is done now) but would have to be handled in comparatively short lengths. This would slow up production to such an extent that it could not be tolerated.

Let us suppose that we have two tungsten ingots made from the same tungsten powder but that one of them has been sintered at the germinative temperature and therefore, is coarse-grained. Let us suppose that the other ingot has been sintered at a temperature above the germinative temperature and consequently is fine grained. Ingots of this nature have been made, in which the grain size was 50,000 times as great in the coarse as in the fine-grained sample. These two ingots can be worked and treated in such a manner that when small wires are produced from them, they will be practically identical in structure. Both ingots are first swaged until their length has been about doubled or has reached some other suitable length; then these swaged rods are heated in an atmosphere of hydrogen by the passage of an electric current to a temperature above that of equiaxing. The result in an individual case was as follows:—

Before treatment, the grain size ratio in the two ingots was 50,000 to 1; after swaging to 100 per cent. elongation and reheating to above the equiaxing temperature, the grain-size ratio was 4:1. Fig. 36 shows a longitudinal section of the fine-grained ingot after swaging and reheating, and Fig. 37 a longitudinal section of the coarse-grained ingot after swaging and reheating. After an additional swaging and reheating, the grain size of the two rods will be practically identical. This process can be used to equalise the structures of the tungsten rods when desirable. Fig. 38 is a typical example of a longitudinal section of a swaged tungsten rod. Fig. 39 is a micrograph of a similar tungsten rod after heating for 3 minutes to a temperature of 3,100 deg. C.

Tungsten rods which have been worked and recrystallised are stronger than sintered rods. In the sintered rods, the grains are exactly equiaxed, but in the recrystallised rods the grains are longer in a longitudinal than in a transverse direction.

Equiaxing Temperature of Worked Tungsten.

The equiaxing temperatures of worked tungsten have been determined with an exposure of 5 minutes. The equiaxing temperature of a swaged tungsten rod which has been reduced in area by working about 24 per cent. is 2,200 deg. C. The equiaxing temperatures are gradually lowered both as the degree of deformation increases and as the temperatures of working decrease. Both of these factors serve to give tungsten a long equiaxing temperature range. When the swaging process has been carried on so as to reduce the area by working about 90 per cent., the equiaxing temperature is 1,800 deg. C. for a period of 5 minutes. With the very small tungsten wires which have been reduced in area 99·99 per cent. or more, and which have been finished at a comparatively low temperature, say a dull red heat, the equiaxing temperature in a period of 5 minutes will be in the neighbourhood of 1,350 deg. temperature. The equiaxing temperature also decreases as the time of exposure increases.

Germinative Temperature Phenomena in Worked Tungsten.

When most metals have their grains permanently

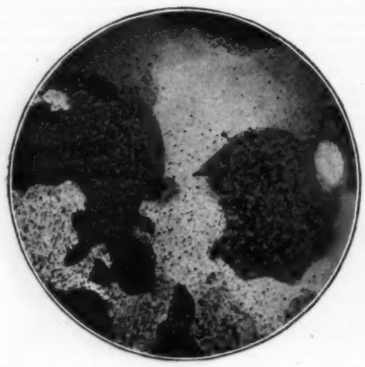


FIG. 29A. TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2, HEATED 20 MIN. AT 2,600 DEG. CENT. AND THEN HEATED 10 MIN. AT 3,200 DEG. CENT. × 74.

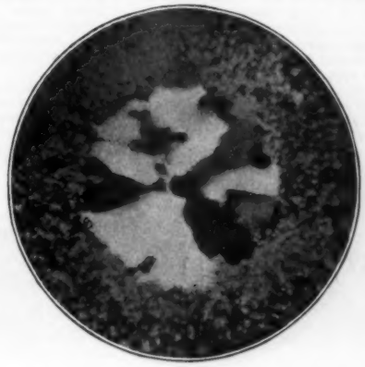


FIG. 30. FINE-GRAINED TUNGSTEN INGOT WITH FUSED CENTRE. × 15.

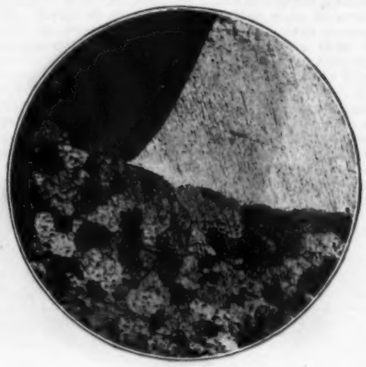


FIG. 30A. FINE-GRAINED TUNGSTEN INGOT WITH FUSED CENTRE. × 144.

FIG. 31. COARSE-GRAINED TUNGSTEN INGOT WITH FUSED CENTRE. × 17.

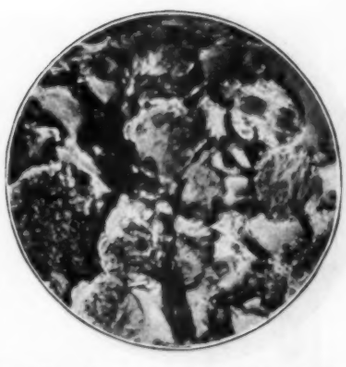


FIG. 32. INGOT WITH TUNGSTEN-CARBIDE NETWORK SURROUNDING TUNGSTEN GRAINS. × 950.

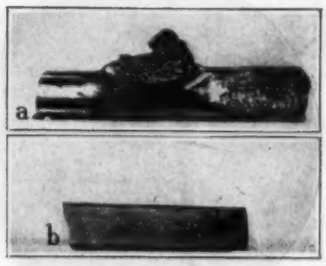


FIG. 33. *a*. TUNGSTEN INGOT CONTAINING BOTH ThO_2 AND CARBON. *b*. TUNGSTEN INGOT CONTAINING ONLY ThO_2.

FIG. 34. TUNGSTEN ROD CARBONISED WITH CO. LIGHT PORTION IS TUNGSTEN CARBIDE. × 940.

FIG. 35. TUNGSTEN ROD CARBONISED WITH HYDROCARBONS. LIGHT PORTION IS TUNGSTEN CARBIDE. × 400.

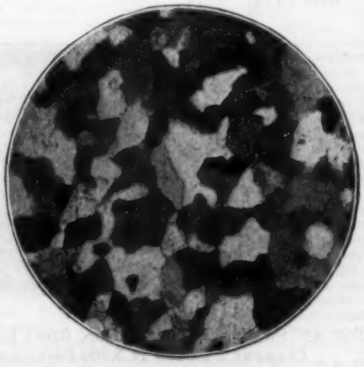


FIG. 36. FINE-GRAINED TUNGSTEN INGOT. SWAGED AND RECRYSTALLISED. × 74.

deformed, a slight amount, say corresponding to a reduction of area of 1 per cent. or more, but usually not more than 20 per cent. or 30 per cent., germinative temperature phenomena are apt to render them coarse-grained during a normal annealing process. With ordinary muffle heating, there is apt to be no temperature gradient, or at most a very slight one, and a moderate deformation will cause within the metal a strain gradient which will cause germinative grains to form at suitable temperatures with the consequent production of coarse-grained structures.

When tungsten is deformed a moderate amount, say a few per cent. reduction in area, it should form these coarse grains at its germinative temperature, and it probably would if it were heated in a muffle to a temperature of about 2,300 deg. or 2,400 deg. C. When such a piece of tungsten, however, is heated by the passage of an electric current, the strain gradient has its maximum strain near the surface of the sample (at the point of application of the deformational forces) and the point of minimum strain is at the axis of the tungsten rod. When this rod is heated by passing an electric current through it, its axis is heated to a higher temperature than its surface. The temperature gradient therefore, serves to counterbalance the strain gradient in such a manner as to defeat the formation of coarse grains.

As the degree of deformation increases, however, the strain gradient from surface to axis of the tungsten rod becomes practically nil. The temperature gradient during heating or during a sojourn at a certain high temperature will still obtain. Germinative temperature phenomena are then apparent in worked tungsten. When a tungsten rod has been swaged from 0·250 in. (6·35 mm.) to 0·080 in. (2·03 mm.), coarse grains can be produced by maintaining the 0·080-in. rod at a temperature just above that of equiaxing for an extended period of time. Coarse grains may also be produced in these 0·080-in. swaged rods by heating gradually with electric current to a very high temperature. Fig. 40 is a micrograph of a sample of 0·080-in. swaged tungsten rod heated to a temperature of 3,100 deg. C., the time of heating being about 10 seconds. Fig. 41 shows a piece of the same 0·080-in. swaged tungsten rod which was heated as quickly as possible to 3,100 deg. C. It will be noted that the sample that was heated quickly is comparatively fine-grained and the sample that was heated more slowly is extremely coarse-grained. The sample shown in Fig. 41 can be maintained at a temperature of 3,100 deg. C. for hours without changing its grain size noticeably. This shows that a variation in the change of rate of heating of 10 seconds may have more influence on the resulting grain size than an exposure of many hours, or even many days, at the highest temperature reached. All rates of heating requiring more than 10 seconds to reach 3,100 deg. C. will produce coarse-grained structures in these 0·080-in. rods. The heating of an 0·080-in. swaged tungsten rod to a temperature of 2,800 deg. C. in a period of 10 seconds or more will result in a coarse-grained structure.

It should be noted in this respect that the presence of thoria in swaged tungsten operates against the formation of these large grains. It should also be noted that all of the heating is done by passing electric current through the metal itself in an atmosphere of hydrogen, thus causing a temperature gradient to exist in the heated sample. These examples of rapid grain growth are with tungsten ingots containing no thoria.

At a temperature of 2,750 deg. C., the rate of heating must be 11 seconds or more in order to produce the coarse-grained structure. At a temperature of 2,700 deg. C., if the time of reaching that temperature is less than 7½ minutes, the structure will be fine-grained, whereas if the time is more than 7½ minutes, the structure will be coarse-grained. At a temperature of 2,600 deg. C., the time of heating to that temperature must be more than 20 minutes in order to produce a coarse-grained structure. In these remarks, a coarse-grained structure indicates the very coarse-grained structure produced under exaggerated grain-growth conditions. These time periods will also change with the particular material used.

If the 0·080-in. tungsten wire is held at a mean temperature slightly above the equiaxing temperature for an extended time, large grains will form according to the regular germinative temperature law. Fig. 42 illustrates this grain growth at constant mean

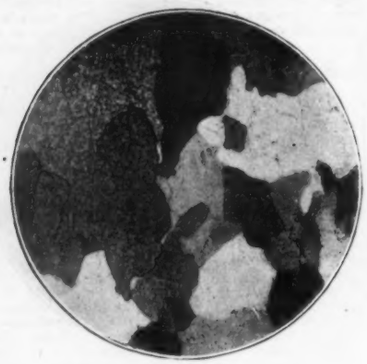


FIG. 37. COARSE-GRAINED TUNGSTEN INGOT, SWAGED AND RECRYSTALLISED. × 74.

FIG. 38. STRUCTURE OF SWAGED TUNGSTEN ROD, 0.80 IN. DIAMETER. × 240.

FIG. 39. SWAGED TUNGSTEN ROD CONTAINING 0.75 PER CENT. ThO_2, 0.080 IN. DIAMETER. RECRYSTALLISED BY HEATING 3 MIN. AT 3,100 DEG. CENT. × 240.

FIG. 40. SWAGED TUNGSTEN ROD CONTAINING NO ThO_2. 0.080 IN. DIAMETER. HEATED BY ELECTRIC CURRENT SLOWLY TO 3,100 DEG. CENT. × 73.

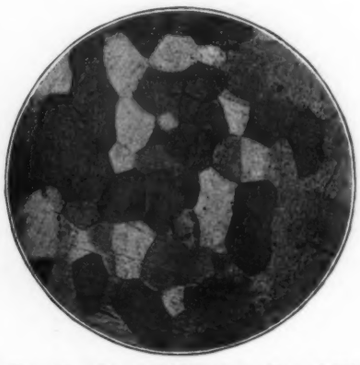


FIG. 41. SWAGED TUNGSTEN ROD, 0.080 IN. DIAMETER, CONTAINING NO ThO_2. HEATED BY ELECTRIC CURRENT QUICKLY TO 3,100 DEG. CENT. × 73.

FIG. 43. SWAGED TUNGSTEN ROD, 0.080 IN. DIAMETER, CONTAINING 0.75 PER CENT. ThO_2. HEATED 9¾ HOURS AT 3,000 DEG. CENT. COLD END NEAR ELECTRODE CLAMP. × 155.

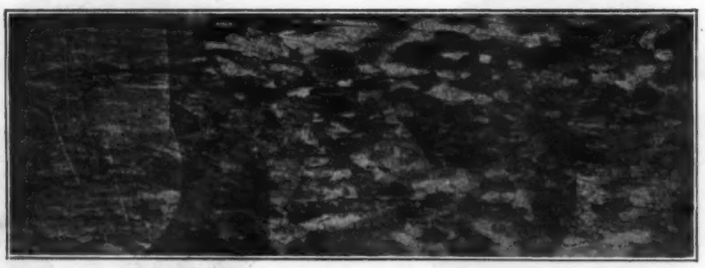


FIG. 42. SWAGED TUNGSTEN ROD, 0.080 IN. DIAM., CONTAINING NO ThO_2. HEATED BY ELECTRIC CURRENT 2 HOURS AT 3,000 DEG. CENT. END NEAR COLD ELECTRODE CLAMP. × 33.

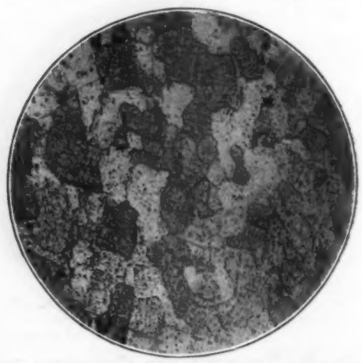


FIG. 44. SAME ROD AS FIG. 43, IN HOTTER REGION × 155.

temperature, and a constant temperature gradient. This is a micrograph of an 0·080-in. swaged tungsten rod which has been reheated to a comparatively high temperature. The micrograph shows that portion which was held in the electrode clip and also the portion near the clip. It will be seen that on the left of the micrograph the grains are deformed. This was obviously the coldest portion. Temperature gradients in two directions would obtain near the electrode clip. There would be an axial temperature gradient and a radial one. The portion at the extreme right of the micrograph was above the germinative temperature, and this portion exhibits a rather uniform grain size throughout. At all portions, however, between the unrecrystallised portion and the extreme right of the micrograph, the germinative temperature has existed in some part of the rod. In the hotter zone, the germinative temperature has been near the surface, and in the cooler regions, near the axis of the rod. The germinative temperature areas can be seen readily in this micrograph, although sufficient time was not given for the germinative temperature regions to encroach upon the smaller grains of either the hotter or colder portions of the sample. This figure, therefore, represents the first stages of grain growth in the germinative temperature region. Fig. 43 is a micrograph of a similar sample after the germinative grains have reached a larger comparative size. Fig. 44 is a micrograph of the same sample as Fig. 43 in the hotter portion which was above the germinative temperature. It will be noted that the colder germinative temperature portion has produced larger grains than the hotter portion which was above the germinative temperature.

When an 0·080-in. swaged tungsten rod is held at its germinative temperature, it takes considerable time for the coarse grains to form on the entire cross-section of the rod. As the size of the tungsten wire becomes smaller, sometimes a few seconds at the germinative temperature is sufficient to cause the formation of coarse-grained structures. The presence of thoria also impedes the formation of large grains in these small tungsten wires.

Table II shows the minimum time required to change tungsten wires originally possessing fibrous structures to coarse-grained structures, and also the variation in the diameter of wire and in the temperature to which it is heated. The tungsten wires used in these experiments did not contain thoria. The thoriated wires sometimes take as long as 1,000 hours to 1,500 hours to change into the coarse-grained structures unless the temperature be maintained at the germinative temperature. In this event, a few hours only are required to form the coarse-grained structure. It should be noted from Table II that tungsten wires 0·004 in. in diameter form coarse-grained structures easily, whereas tungsten wires 0·005 in. in diameter or greater seem reluctant to form the coarse grains when the temperature is maintained constant either at or above the germinative temperature. The coarse grains form more quickly at the germinative temperature than they do at higher temperatures, but there is a marked difference in time required to form the coarse-grained structures at the germinative temperature between the tungsten wires less than 0·005 in. (0·127 mm.) diameter, and more than 0·005 in. diameter.

In the smaller tungsten wires, say below 0·005 in. diameter, containing no thoria, it will be noted that coarse-grained structures are formed in comparatively short time periods when the temperature is raised above the germinative temperature very quickly and maintained above the germinative temperature. The coarse grains form more readily, however, in these wires at the germinative temperature than at higher temperatures. Furthermore, a slow heating through the germinative temperature range will produce coarse-grained structure very much more readily than a rapid heating past the germinative temperature range followed by a sojourn at the higher temperature. If the diameter of the wire is more than about 0·005 in., the easiest way to form the coarse-grained structures is by slow heating through the germinative temperature range followed by a sojourn at a higher temperature. It can be seen from Table II that it may take as long as an hour to form coarse-grained structures with wires 0·005 in. or greater in diameter either when held at the germinative temperature or above it. Coarse-grained structures in these samples, however, can be produced in a few seconds by heating the wire slowly through the germinative temperature range.

TABLE II.

Diameter of Wire in Mils.	Temperature in Deg. Cent.	Minimum Time Required to Change to Coarse-Grained Structure.	
		minutes	seconds
3	3100	3	0
3	2900	2	45
3	2800	2	0
3	2700	0	45
3	2650	0	30
3	2600	0	7
3	2550	0	20
3	2500	0	20
4	3100	more than 2	30
4	2900	3	0
4	2800	3	0
4	2700	2	45
4	2650	2	45
4	2600	2	45
4	2550	1	45
4	2500	1	0
5	2900	13	0
5	2800	more than 30	0
5	2700	more than 30	0
5	2650	more than 28	0
5	2600	more than 40	0
5	2550	more than 60	0
5	2500	more than 40	0
6	2900	more than 30	0

Fig. 45 is a typical example of the fine-grained structures produced in these experiments and Fig. 46 is a typical example of the coarse-grained structures.

The formation of coarse-grained structures during a gradual heating through the germinative temperature range needs further consideration here. The effect of heating so quickly that germination does not have time to assert itself in the germinative temperature range has already been considered. In the pressed tungsten slug, for example, a heating period of 6 minutes can be used to attain the highest temperature without any exaggerated growth. Some of the swaged tungsten rods, however, and also the small drawn wire, must be heated through the germinative temperature range in less than 10 seconds to defeat the formation of the coarse-grained structures. The germinative temperature will be lower as the time of heating is increased. For example, if a tungsten wire is heated by electric current to a temperature just above that of equiaxing and held there for an indefinite time, coarse grains will be formed for reasons discussed above. If, however, the tungsten wire is held at a temperature several hundred degrees above the equiaxing temperature for a short time, a coarse-grained structure may be produced in a shorter time. If the tungsten rod is heated to a temperature far above that of equiaxing, fine grains will first form. They may change to large grains due to normal grain growth, but not by germination; or they may remain as small grains.

The equiaxing temperature is a function of the time, and consequently the germinative temperature which depends to a certain extent upon the equiaxing temperature will also be a function of the time. If we could heat a piece of cold-worked copper to 1,000 deg. C. and cool it again to room temperature, the whole cycle taking but a millionth of a second, we would find that the structure of the wire had not been materially changed, nor would the properties at room temperature be changed. In other words, cold-worked copper which will recrystallise or equiaxe at a temperature of 250 deg. C. if sufficient time be given, will not equiaxe or recrystallise in a millionth of a second at a temperature 750 deg. higher. Experiments of this nature have been conducted on tungsten wire. The wire can be flashed to a temperature near its melting-point and quickly cooled to room temperature without apparent change in its structure or properties. Recrystallisation of deformed grains involves a certain time period. If the temperature is comparatively low, the time is long, and *vice versa*.

When a fibrous tungsten wire is heated at a rapid rate by means of electric current, but not so rapid that the germinative temperature laws are masked, germinant grains will form at some temperature depending upon the rate of heating. These germinant grains should be able to absorb both hotter and colder smaller grains faster than these smaller grains can coalesce with one another. When this condition obtains, coarse-grained structures will result. The gradual rise in temperature favours the absorption of the smaller grains by the larger germinant grains. The grain growth becomes a race between the germinant grains and the smaller grains. This race is in its critical period at the beginning of germination. After the germinant grains have once acquired a size much larger than the mean size of the smaller grains, the latter are absorbed readily at any temperature in the grain-growth region.

Another example of germinative temperature conditions is shown in Fig. 47, a micrograph of a molybdenum hook used to support tungsten filaments in electric incandescent lamps. This hook was in the fibrous condition when it was put in the lamp. It has been heated in the lamp from the heat of the tungsten filament which it supported and with which it was in contact at one point only, namely, at the bottom of the loop portion. It received heat by conduction and radiation from the coiled tungsten filament. There would be temperature gradients in two directions in this wire, one axially and one radially. The combination of these two temperature gradients has produced the structure seen in Fig. 47. It will be noted that at the point of contact between the

FIG. 45 TUNGSTEN WIRE, 0.003 IN. DIAMETER, CONTAINING NO ThO_2. HEATED BY ELECTRIC CURRENT QUICKLY ABOVE GERMINATIVE TEMPERATURE. × 355.

FIG. 46. SAME WIRE AS FIG. 45. HEATED BY ELECTRIC CURRENT SLOWLY THROUGH GERMINATIVE TEMPERATURE RANGE. × 355.

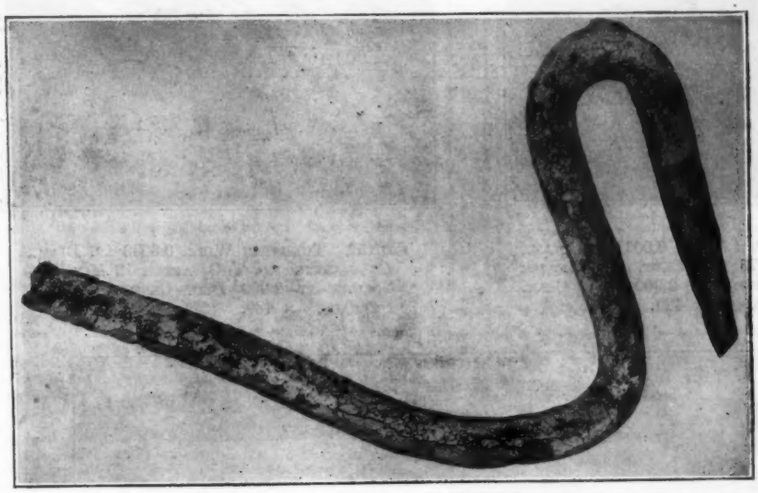


FIG. 47. MOLYBDENUM HOOK USED AS FILAMENT SUPPORT IN 1,000-WATT GAS-FILLED LAMP. LONGITUDINAL SECTION. × 78.

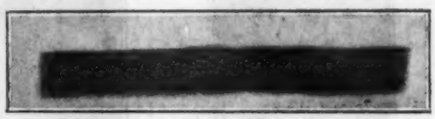


FIG. 48. TUNGSTEN WIRE, 0.007 IN. DIAMETER, CONTAINING 0.75 PER CENT. ThO_2. RECRYSTALLISED BY SHORT HEATING AT ABOUT 2,000 DEG. CENT. × 130.

tungsten wire and the molybdenum hook, the latter is fine-grained. The temperature at this point was above the germinative temperature. At points more remote from the point of contact between the hook and the filament, there is every gradation in structure from fine-grained throughout to coarse-grained throughout. At in grain size for a given time between 2,500 deg. C. and 3,000 deg. C. is more marked.

Tungsten ingots during sintering also attain an approximate equilibrium grain size for a given temperature in a few minutes. This is especially true at the higher temperatures of sintering, say, 3,200 deg. C., whereas, if the sintering is done at a lower temperature, a longer time is necessary for an approximate equilibrium grain size to be produced.

Structure and Properties of Tungsten Filaments after Use.

Tungsten incandescent electric lamps are all so

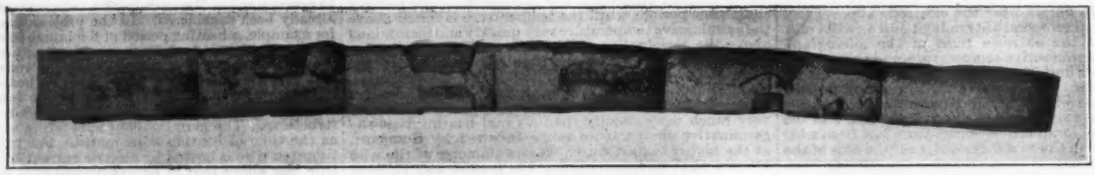


FIG. 49. TUNGSTEN FILAMENT 0.0015 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 AFTER BURN-OUT IN 40-WATT VACUUM LAMP. LONGITUDINAL SECTION. × 346.

FIG. 50. OLD TYPE "SQUIRTED" TUNGSTEN FILAMENT AFTER BURN-OUT IN VACUUM LAMP. (YOUNG.) × 325.

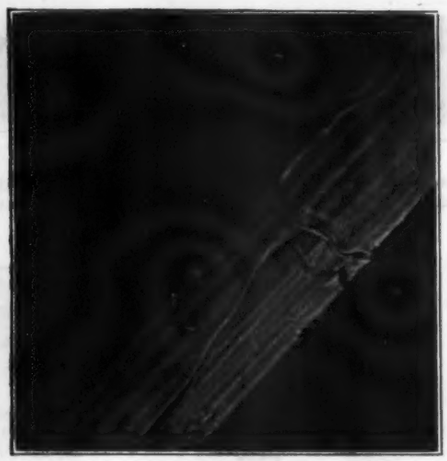


FIG. 51. TUNGSTEN WIRE, 0.0036 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 AFTER 10 MIN. EXPOSURE AT 2,900 DEG. CENT. NATURAL SURFACE. × 480.

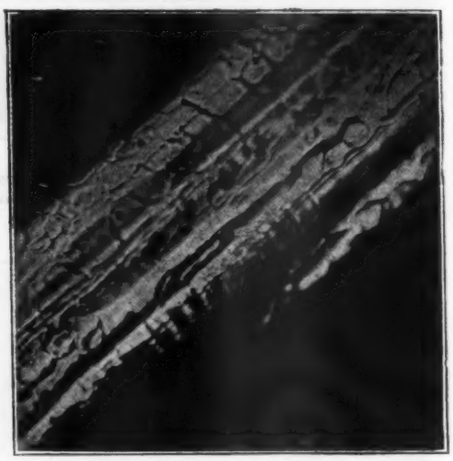


FIG. 52. TUNGSTEN WIRE, 0.0036 IN. DIAM., CONTAINING NO ThO_2 AFTER 10 MIN. EXPOSURE AT 2,900 DEG. CENT. NATURAL SURFACE. × 480.

FIG. 53. TUNGSTEN WIRE, 0.007 IN. DIAM., CONTAINING NO ThO_2. USED AS FILAMENT IN VACUUM LAMP AFTER 66 HOURS BURNING. SHOWS BOTH LARGE GRAINS AND ABSENCE OF GRAIN BOUNDARIES EXTENDING ACROSS WHOLE SECTION OF WIRE. × 60.

the contact between the recrystallised and unrecrystallised portion (shown at the extreme right of Fig. 47) the molybdenum hook is very brittle. It is ductile in the fully recrystallised region and also in the unrecrystallised region.

THE EFFECT OF TIME AND TEMPERATURE ON THE GRAIN SIZE IN TUNGSTEN.

A series of experiments was carried out on swaged tungsten rods 0·075 in. diameter made from tungsten metal of three different varieties. Two of the sets of samples contained 0·75 per cent. thoria and the third set contained no thoria. The results of these experiments are given in Table III.

This table shows plainly that the increase in grain size with increase in time is not regular. It is as regular, however, as might be expected with different samples. At the time these experiments were carried out, the writer was not aware of the extreme rapidity of the formation of germinant grains during heating. Some of the radical results indicated in Table III were found later to have been caused by the germinative temperature conditions during heating.

The conclusions reached from the results given in Table III are as follows:—

1. Recrystallisation is complete in less than 30 seconds at temperatures of 2,500 deg. C. or above. Aside from the germinative temperature phenomena, grain growth has established an approximate equilibrium grain size at the end of 30 seconds. Further heating for 9¼ hours increases the grain size but slightly.

2. In the tungsten rods containing thoria, the difference in grain size between a temperature of 2,500 deg. C. and a temperature of 3,000 deg. C. with the time period constant is very slight.

3. With tungsten containing no thoria, the difference

TABLE III.

	Kind of Metal.	Temperature, Deg. C.	Time of Exposure. Hrs.	Min.	Sec.	Grains per Sq. Mm.
(A)	per cent. thoria	2,500	0	0	30	3,400
	per cent. thoria	2,500	0	1	0	2,700
	per cent. thoria	2,500	0	5	0	2,700
	per cent. thoria	2,500	0	25	0	2,200
	per cent. thoria	2,500	2	0	0	3,000
	per cent. thoria	3,000	0	0	30	2,300
	per cent. thoria	3,000	0	1	0	2,200
	per cent. thoria	3,000	0	5	0	2,500
	per cent. thoria	3,000	0	25	0	1,800
	per cent. thoria	3,000	2	0	0	2,300
	per cent. thoria	3,000	9	45	0	2,200
(C)	No thoria ..	2,500	0	0	30	1,700
	No thoria ..	2,500	0	1	0	1,900
	No thoria ..	2,500	0	5	0	2,800
	No thoria ..	2,500	0	25	0	1,000
	No thoria ..	2,500	2	0	0	1,600
	No thoria ..	3,000	0	1	0	900
	No thoria ..	3,000	0	5	0	1,500
	No thoria ..	3,000	0	25	0	1,100
	No thoria ..	3,000	2	0	0	900
(D)	per cent. thoria	2,500	0	0	30	2,000
	per cent. thoria	2,500	0	1	0	2,300
	per cent. thoria	2,500	0	5	0	1,700
	per cent. thoria	2,500	0	25	0	2,100
	per cent. thoria	2,500	2	0	0	1,800
	per cent. thoria	2,500	9	45	0	1,600
	per cent. thoria	3,000	0	0	30	1,900
	per cent. thoria	3,000	0	1	0	2,000
	per cent. thoria	3,000	0	5	0	1,900
	per cent. thoria	3,000	0	25	0	2,000
	per cent. thoria	3,000	2	0	0	1,700

designed that when the lamps are used at rated voltage the temperature of the filaments will be above the recrystallisation or equiaxing temperature of tungsten. This is especially true when the long time of heating of the filaments is considered. Since the operating temperatures of lamp filaments are in the grain growth region of tungsten (above the equiaxing temperature and below the melting-point) and since the time of heating in this grain-growth range is long, sometimes exceeding 1,500 hours, the structure of the filament will change during the life of the lamp. After a short burning, tungsten wires containing thoria will possess structures similar to that shown in Fig. 48. It will be noted that the grains are longer in the direction of the working than in a perpendicular direction. During the life of the lamp, this elongation is even more marked. Fig. 49 is a micrograph of a 40-watt tungsten filament after burn-out. This filament contained thoria. It will be noted that the grains have been greatly elongated during the life of the lamp. These grains are equilibrium grains so far as deformational strains are concerned. The growth in a longitudinal direction has been more rapid than in an axial direction. The underlying causes for this type of grain formation have been studied, and the following conclusions have been reached:

The spherical thoria globules existing in the tungsten ingot before working are elongated during the working operations. They do not, however, elongate as much as the metallic grains. The drawn tungsten wire will consist of metallic fibres of tungsten elongated in the direction of working and non-metallic fibres or miniature rods of thoria parallel to the metallic tungsten fibres. When this wire is heated above its equiaxing temperature, the metallic fibres will change into very small equiaxed grains, but the thoria rods, if they change at all, only break up into rows of spheres, each row occupying

the same general position as the thoria rod from which it was formed. Even the breaking up of the thoria into spheres takes considerable time. After the metallic grains of tungsten have broken up into very small equiaxed grains, these coalesce with one another, forming fewer and larger grains. Grain growth will take place in accordance with the time, temperature and resistance to grain growth. The resistance to grain growth in an axial direction will be much greater than in a longitudinal direction. In an axial direction, the thoria rods, or rows of thoria spheres, will present much more surface to resist grain growth than in a longitudinal direction, because the sides of the thoria rods will offer resistance to radial grain growth. Only the ends of the thoria rods, however, will offer resistance to grain growth in a longitudinal direction. By calculation, it can be shown that the resistance to grain growth in an axial direction due to the presence of thoria may be more than 50 times that in a longitudinal direction.

It will be seen later that the forced formation of the elongated grains in a tungsten filament makes it very much more rugged than it would have been had the grains been exactly equiaxed. Fig. 50 is a micrograph of one of the old squirted or pressed tungsten filaments after life test. This micrograph was kindly furnished by Mr. C. D. Young, of the Pennsylvania Railroad Company. It will be noted that the grains in this wire are equiaxed. This is the structure which renders tungsten extremely brittle and fragile at ordinary temperatures, whereas the structure shown in Fig. 49 renders tungsten rugged at room temperature. The reasons for this will be discussed later.

A great many different types of structure are encountered in tungsten filaments after they have been used for various lengths of time. Fig. 49 is a typical example.

The difference in resistance to grain growth between tungsten containing thoria and tungsten containing no thoria can be seen by referring to Figs. 51 and 52. Fig. 51 contains 0·75 per cent. thoria and Fig. 52 no thoria. Both wires have been heated for 10 minutes to a temperature near 2,850 deg. C. These micrographs are of the natural surfaces of the wires. The boundary material of the grains volatilises more rapidly than the crystalline material, so that the grain boundaries can be seen without etching.

If tungsten develops very coarse grains when used as a filament, it has the property of being much stiffer at high temperatures than when composed of fine grains. The wires will not sag due to their own weight even when heated to a temperature of about 2,800 deg. C. If the filament, however, is fine-grained, it may sag badly due to its own weight. There is danger in producing coarse-grained structures, because if a boundary line between two grains cuts sharply across a section of the filament on a plane approximately perpendicular to its axis, one section of the filament may be displaced in a direction perpendicular to its axis, thus causing the phenomenon known as "offsetting." We now know that at the boundaries between two tungsten grains a film of amorphous tungsten exists (this assumes the validity of the amorphous theory) and that at the temperatures at which the lamp filaments are used, this amorphous film is more or less fluid and weak mechanically. This is why the fine-grained tungsten wires are weaker at high temperatures than the coarse-grained tungsten. This is also the reason that offsetting takes place at the grain boundaries traversing the whole cross-section of the wire.

It is possible to form tungsten wires which are both coarse-grained and substantially non-offsetting. Fig. 53 is a micrograph of a tungsten filament that is both coarse-grained and non-offsetting. It can be noted that these grains are very long in a direction parallel to the axis of the wire, and that at no place does a grain boundary extend across the diameter of the wire in such a way that offsetting can take place.

Weldability of Tungsten.

Many attempts have been made to weld the particles of tungsten together by working at a very high temperature. No headway has been made in this direction. To be workable, a piece of tungsten must be substantially non-porous—that is, the individual particles must have been previously welded together at a temperature near the melting-point of tungsten in an atmosphere of hydrogen or other gas which is either helpful or at least not harmful to the tungsten.

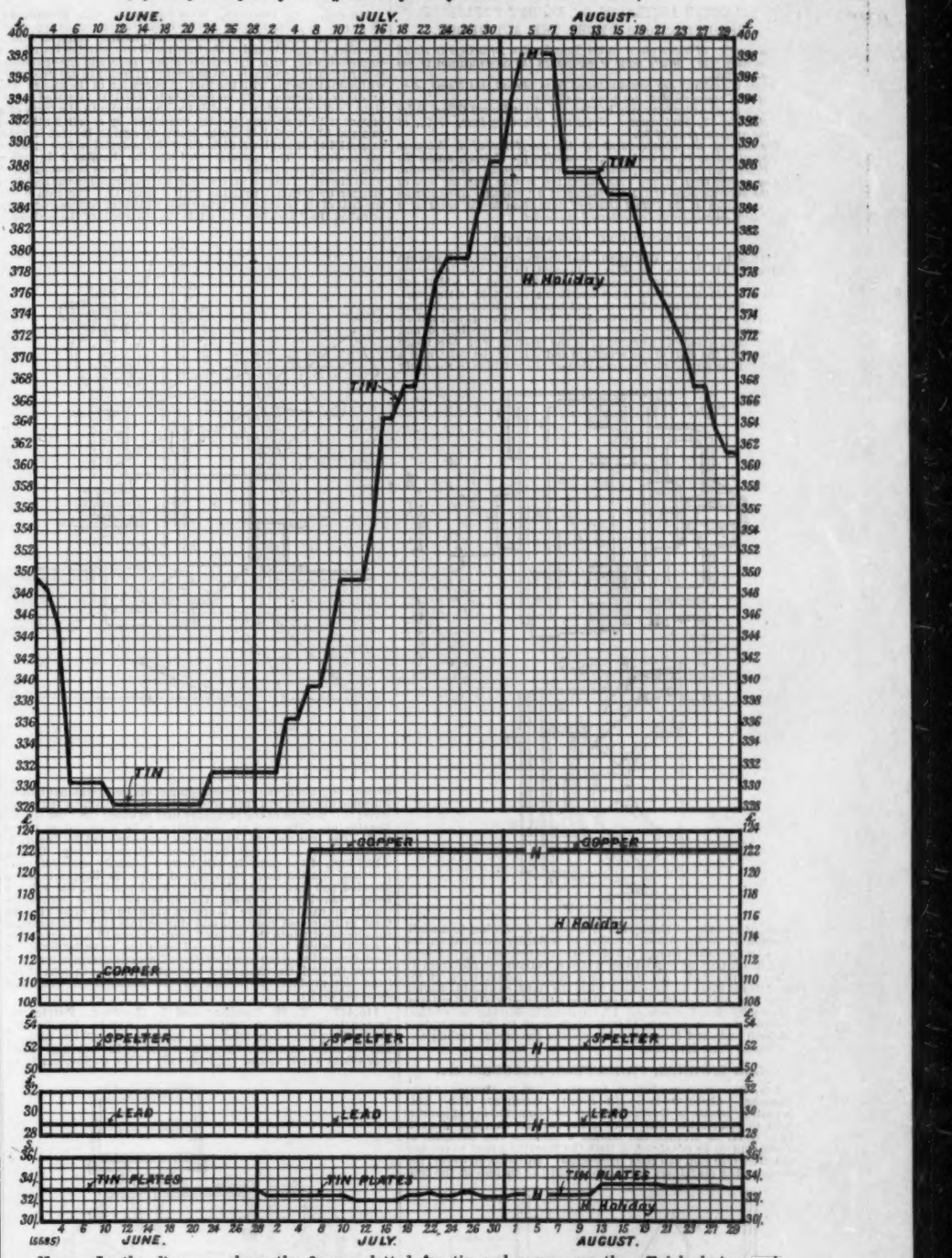
Sometimes the swaged tungsten rods split during the swaging operation. Attempts have been made to weld these split portions together by working at a high temperature. The highest temperature available was 1,700 deg. to 1,800 deg. C. It was not found possible to weld the tungsten in this manner. Tungsten can be welded electrically at temperatures near fusion.

(To be continued.)

MAGNETIC ELEMENTS IN 1917.—The year 1917 was rich in magnetic storms, yet less so than might have been expected from the unusual development of sun spots which had been much increasing since 1915. The Wolf-Wolfer numbers, which refer both to the numbers and intensities of the sun spots, for the years 1915, 1916, 1917 were 46·0, 55·4, 98·8, showing a very strong increase in 1917, therefore. According to the observations conducted at the Potsdam magnetic observatory, the average values of magnetic elements for the year 1917 were: Destination 7 deg. 58·4 minutes west, the dip 66 deg. 29·2 minutes north, horizontal intensity 0·18671 c.g.s. unit. The differences between the years 1917 and 1916 were — 9·2 minutes in destination, + 2·1 minutes in dip, and — 27 γ in horizontal intensity (γ being 0·00001 unit); these changes are in good accord with those of recent years.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig iron was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

COLLECTION OF CONTROLLED SCRAP.—The Ministry of Munitions announces that a large number of metal merchants have been authorised to purchase and collect controlled scrap metals in quantities below those scheduled in the Prevention of Crimes Act, 1871; and all persons having in their possession small quantities of scrap copper and lead are requested to dispose of the same to one of the duly authorised merchants as early as possible. Collecting merchants who desire to be authorised to collect scrap in small quantities should apply to the Controller of Non-Ferrous Materials, Supply, Room 620, 8, Northumberland-avenue, W.C. 2.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

ELECTRICAL APPARATUS.

116,571. J. W. Burleigh, Burnham-on-Sea. Dynamo Electric Machines. (4 *Figs.*) June 29, 1917.—This invention relates to dynamo-electric machines of the kind in which end brackets which carry the shaft bearings are secured to the yoke. According to this invention, the end-bearing brackets are formed with two parallel and radial flanges 1, 2, spaced apart and united by webs 3 for the purpose of providing radial openings 6 and direct connection of the exterior of the machine with the space in front of the ends of the armature and sides of the yoke, and a path for the flow of air from one side of the machine to the other

Fig. 1.

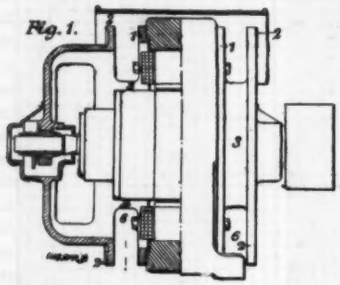
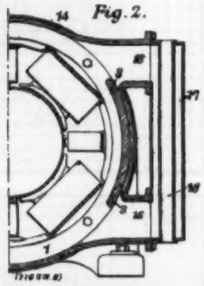


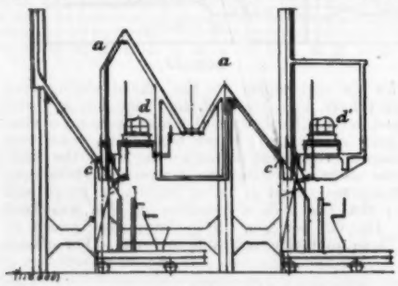
Fig. 2.



without any abrupt changes in direction. According to a modification of the invention, a casing 14 is fixedly mounted on the parallel and radial flanges 1, 2 of each of the end-bearing brackets, and has a port or ports 15 to which a radiator or radiators 17 may be attached. According to a further modification of the invention, there is combined with the fixed casing 14, having inlet and outlet ports 16, a radiator comprising a vertical and externally-closed chamber 17, preferably having a vertical internal tube 18 passing therethrough, open to the atmosphere at both ends and forming a flue for the passage of cooling air. (*Accepted June* 26, 1918.)

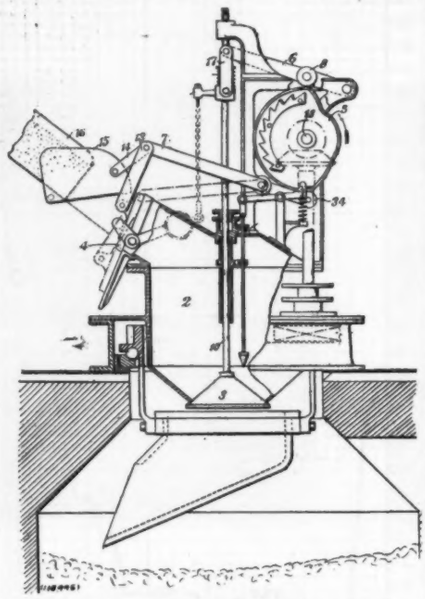
GAS ENGINES, PRODUCERS, HOLDERS, &c.

116,680. Simon-Carves, Limited, and S. Hunter, Manchester. Coke Ovens. (2 *Figs.*) March 21, 1918.—This invention relates to storage bunkers and compressing apparatus used in connection with coke ovens for the charging thereof. It is usual to arrange the bunker a between two batteries of ovens and so to construct it that the travelling feed boxes and the discharge ram can pass therebelow. Hitherto, however, the compressing machinery for compressing the charges in the feed



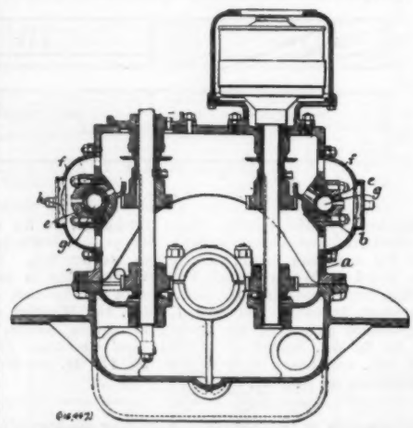
boxes has been arranged at either side of the storage bunkers at the outside thereof, both shoots from the bunkers delivering outwards or in opposite directions. With such arrangement, it is necessary to employ travelling feed boxes of opposite hand and to arrange the compressing machines so that the stamps which compress the coal fed into the feed boxes from the bunker are at opposite sides, with the result that each feed-box can feed and serve only at its side of the batteries. According to the invention, one of the compressing machines d^1 is arranged outside of the bunker *a*, as usual, and the other *d* is arranged inside of the bunker, and both shoots *c*, c^1, deliver in the same direction. (*Accepted June* 26, 1918.)

116,445. F. Thuman, Westminster. Gas Producers. (5 *Figs.*) October 25, 1917.—This invention relates to apparatus of the kind designed for automatically feeding material into a chamber without bringing the interior of the chamber into direct communication with the outside atmosphere, and the invention is particularly applicable to the feeding of fuel into gas producers without interfering with the routine operation of the plant. The producer is formed with an opening in which is mounted a gas-tight feeding chamber 2, which has the bottom in the form of a hopper with a circular opening controlled by a bell 3 attached to a rod 10 by which it can be drawn up against its seat to form a gastight joint or lowered to allow the material to flow into the gas producer. The material is fed into the chamber 2 through a side opening controlled by a slide-valve 4, which is also gastight when closed. The two valves 3 and 4 are operated in the required manner by a cam 5 rotating with a shaft 18. The cam 5 has one-half of its periphery a true circle which for convenience may be called the "high level"; while the other half of the periphery



descends by a curve to a circle of smaller diameter which it follows for some distance and then gradually ascends again to the upper level; this portion of the periphery may be called the "low level." Bearing upon the cam are two rollers 8, 34, mounted on levers 6, 7. The free ends of these levers are connected by the links 17, 13 to valve rod 10 and the slide-valve 4, respectively. During a half-turn of the cam, the bell valve 3 descends to its full open position, remains there for a period while the hopper is being emptied and then reascends to its closed position, the valve 4 being meanwhile kept closed. During the succeeding half revolution of the cam, the valve 4 is opened while the bell valve 3 is held tight in its closed position, and during this time the material runs by gravity into the hopper 2 down a chute 16 and a movable spout 15, which latter is actuated with the valve by links 14. Each revolution of the cam therefore allows one charge of material to pass through the chamber 2 without allowing a current of gas from the producer to escape to the atmosphere. (*Accepted June* 19, 1918.)

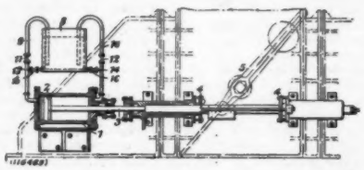
116,447. T. H. Gardner and E. Gardner, Patricroft. Internal-Combustion Engines. (10 *Figs.*) October 26, 1917.—This invention relates to internal combustion engines. The invention comprises the arrangement of the bearings of the cam shafts which extend longitudinally of the engine, partly in



the outer faces of the side walls of the crank-case, the remaining portion of the bearings being provided in caps attached to the crank-case, so that by the removal of said caps the camshafts can be withdrawn from position, and the provision of cover pieces with hand holes and hand-hole doors therein secured to the crank-case over the said cam-shafts. The crank case *a* is provided with portions *b* of the camshaft bearings in the outer faces of each of the webs extending across the crank-case, the remaining portion of each bearing being provided in a detachable cap *e* secured upon the face of the web. Gaps are provided in the crank-case between the webs, and the surface around said gaps is machined to receive the cover pieces *f*, each made in one or more parts, the said cover pieces completely closing in the camshafts *g*, g^1, at the opposite sides of the engine. Hand holes *h* with suitable doors are provided in said cover pieces. When it is desired to withdraw a camshaft, or to gain access to the interior of the crank-case, the appropriate cover piece *f* and detachable caps *e* are removed, when the camshaft can be lifted out of position. The aforesaid arrangement, therefore, provides a ready means of access to the crank-case and obviates the necessity for withdrawing the camshafts in a longitudinal direction. (*Accepted June* 19, 1918.)

HYDRAULIC MACHINERY.

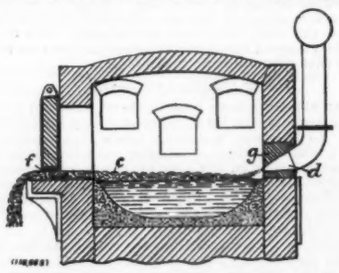
116,465. H. J. Munro, Pontardawe. Fluid-Operated Mechanism. (2 *Figs.*) December 10, 1917.—This invention of improvements in or in connection with means or apparatus used in the control of fluid-operated mechanisms, has relation to the regulating and retarding cylinders employed in connection with the single and double-acting reversing cylinders used for working rolling-mill manipulators, engine valve gear, feed mechanism of hot sawing machines, operating the reversing gas and air valves of open-hearth melting and reheating furnaces and in other connections. The invention consists in connecting the regulating and retarding cylinder at both ends with the lower portion of a reservoir of liquid, such as oil or water, through an additional pipe which acts as a suction pipe and contains a non-return valve. 1 is the cylinder of the regulating and retarding means and 2 is the piston therein. The piston 2 is connected by a piston rod 3 with the single acting rams 4 of the fluid-operated mechanism actuating a reversing valve 5. 8 is a liquid reservoir connected with both ends of the cylinder 1 by pipes 9, 10, each containing a regulating valve 11, 12, preferably of the screw-down



type. Below the valves 11, 12, other pipes 13, 14, each containing a non-return valve 15, 16, are connected with the pipes 9, 10, and reservoir 8. The pipes 13, 14, together with the portions of the pipes 9, 10, below the valves 11, 12, form the suction pipes and, owing to their connection with the reservoir 8, draw the oil from the lower part thereof. The pipes 9, 10, form the delivery pipes and extend into the reservoir 8 and terminate near to the bottom thereof. With the foregoing arrangement it will be seen that when the piston 2 is moved within the cylinder 1 under the action of one of the rams 4, oil is drawn into one end of the cylinder through, say, the pipe 13, 9 and non-return valve 15, and is discharged from the other end of the cylinder through the pipe 10 and regulating valve 12. The provision of the pipes 13, 14, and non-return valves 15, 16 provides a full-bore suction pipe and permits the cylinder to be filled with oil at each stroke of its piston, which is not the case in known arrangements in which the pipes containing the regulating valves act alternately as suction and delivery pipes, and the valves are set to regulate the movements of the rams 4. (*Sealed.*)

MINING, METALLURGY AND METAL WORKING.

116,663. C. H. F. Bagley, Hartburn, Stockton-on-Tees. Open-Hearth Steel Furnaces. (1 *Fig.*) December 1, 1918.—This invention relates to an improved process and apparatus for removing molten slag from open-hearth furnaces by means of blowing. The invention is characterised in that a blast of suitable pressure and volume is delivered through nozzles *d* or blocks of refractory material or water-cooled tuyeres of usual or suitable type inserted through a wall *g* or door of the furnace and directed on to the surface of the bath from such position



and at such angle that when the blast is turned on, the molten slag *c* is blown by a series of jets across the surface of the metal to the other side of the furnace and flows out through doorways or other conveniently placed slag notches or outlets *f*. By this means, the molten slag may be efficiently removed when desired with the minimum of delay and expense and very efficiently, and the process may be completed in a single fixed furnace without disturbance of either the furnace or the metal. (*Accepted June* 26, 1918.)

COST OF TONNAGE.—The highest price, 205·63 dols. per deadweight ton, is to be paid for 34 ships contracted for on the Great Lakes, says *The Marine Journal*, New York. The lowest price, 151 dols., is for an order placed with a California company. Prices for tonnage at yards around New York range slightly below the average, which was enhanced by the high cost of all Great Lakes construction. For a time after England went into the war and before the United States entered, ships could be built cheaper in the American yards than in those of the United Kingdom. This, however, is no longer the case, as shown by the fact that a ship recently contracted for at 180 dols. a ton could have been taken on by British builders for 120 dols. a ton, had these builders been allowed to take private contracts.